JOURNAL OF AGRICULTURAL RESEARCH
DEPARTMENT OF AGRICULTURE

VOL. VII WASHINGTON, D. C., DECEMBER 11, 1916 NO. 11

MACROSIPHUM GRANARIUM, THE ENGLISH GRAIN APHIS

By W. J. PHILLIPS,[1]
Entomological Assistant, Cereal and Forage Insect Investigations, Bureau of Entomology

Although the English grain aphis (*Macrosiphum granarium* Kirby) is widely disseminated throughout the United States and is a familiar pest of long standing, there are some interesting facts connected with its life history that heretofore have escaped observation. The object of this brief paper is primarily to put on record some details of life history and to discuss the interesting color variations in relation to the sexes.

SYNONYMY

Macrosiphum granarium seems to have been described first by William Kirby (1, p. 238, footnote)[2] in 1798. The description verbatim and complete is as follows:

> Possibly this may be the *Aphis avenae* of Fabricius: but as he has given no description of it, I cannot be positive; I shall therefore describe it under the name of *A. Granaria*, viridis, cauda biseta, setis geniculisque pedum nigris.
>
> Aphis avenae, *Fab. Sp. Ins.* ii. p. 386. n. 17. *Gmel.* tom. 1. part IV. p. 2206. n. 52. *Vill. Ent. Eur.* 1. p. 551. n. 50?
>
> Caput falvidu, uti antennarum articulus primus. Oculi nigri. Abdomen obovatum cauda aculeata. Pedes lividi, tarsis geniculisque nigris.
>
> Habitat in *tritici* et *hordei* spicis, aveneque paniculis.

Although meager, the foregoing description agrees with the species known to entomologists by this name. It can hardly be construed as a description of *Aphis avenae* Fab., as has been supposed by some authors. Curtis (3, p. 504) redescribed what he considered Kirby's species in the

[1] The writer wishes to acknowledge his indebtedness to Mr. T. H. Parks, lately of the Bureau of Entomology, for his assistance in conducting breeding experiments in 1909 at La Fayette, Ind., The observations upon which this paper is based were made at Richmond, Ind. (1907–8), La Fayette, Ind. (1909–1912), and Charlottesville, Va. (1915). Mr. J. J. Davis, of the Bureau of Entomology, kindly consented to prepare the synonymy.

[2] Reference is made by number to "Literature cited," p. 480.

Journal of the Royal Agricultural Society and again in his "Farm Insects" (6, p. 289). While there are minor points in Curtis's description and figures which seem to disagree, as a whole they apply quite well for *M. granarium* auct., and it is reasonably certain that he had this species before him when he made his description.

In 1843 Kaltenbach (2, p. 16) described *Aphis cerealis*. Pergande (11, p. 13–23) considered this to be distinct from *M. granarium*, basing his opinion largely on the presence or absence of abdominal maculations. However, this character is unreliable, as has been proved in breeding experiments where individuals showing all degrees of abdominal markings and some without the faintest trace of maculations were reared from the same mother. Most European authors now consider the two species *M. granarium* and *A. cerealis* as synonyms, and on inquiry the following replies have been received from the respective eminent European aphidologists. Under date of February 15, 1913, Prof. Fred W. Theobald writes: "I look upon *cerealis* and *granarium* as the same. I can see no difference." Under date of January 17, 1913, Mr. P. van der Goot writes as follows: "*M. granarium* and *M. cerealis* I must consider as one species." Dr. G. del Guercio has the following to say in a letter dated December 13, 1911:

> I have examined the specimens of *Macrosiphum* or *Siphonophora granariae*. They show some differences on which it may be possible for us to distinguish certain forms, which, however, as far as I am concerned, could never be considered varieties, let alone species. Fundamentally the *Siph. granariae* there (in America) is the *Siph. cerealis* here, and both in fact, secondary differences aside, are the same species. Your specimens have the antennæ a little longer than the body, while in our forms, at least those of Italy and of the European basin of the Mediterranean, the antennæ are shorter than the body. Buckton [7, p. 114–119, pl. 6], in his first volume, gives a good representation of *Siphonophora granariae*. (Free translation from the Italian.)

In 1849 Walker (4, p. 45–46) described this species as *Aphis avenae* Fab. The species was transferred to the genus Siphonophora by Koch (5, p. 186–187) in 1857, to Nectarophora by Oestlund (8, p. 82) in 1887, and finally to the genus Macrosiphum by Schouteden (10, p. 113–117) in 1901. In 1905 Kirkaldy (12, p. 132) proposed the name *M. avenivorum* for *M. granaria* Buckton, nec Kirby, and this must now be considered a synonym of *M. granarium*.

The synonymy as it now stands is as follows:

Macrosiphum granarium Kirby.

Aphis granaria Kirby, 1798, *in* Trans. Linn. Soc. [London], v. 4, p. 238.
? Aphis hordei Kyber, 1815, *in* Mag. Ent. [Germar], 1798, *in* v. 1, pt. 2, p. 211, *nomen nudum*.
Aphis cerealis, Kaltenb., 1843, Monog. Fam. Pflanzenläuse, p. 16.
Aphis granaria Curtis, 1845?, 1860, Jour. Roy. Agr. Soc., England, v. 6, p. 504; Farm Insects, p. 289.
Aphis avenae Walker (nec Fab.), 1849, *in* Ann. and Mag. Nat. Hist., s. 2, v. 3, p. 45–46.
Bromaphis Amyot, 1847, *in* Ann. Soc. Ent. France, s. 2, v. 5, p. 479.
Siphonophora cerealis Koch, 1857, Monog. Pflanzenläuse, p. 186–187.
Siphonophora granaria Buckton, 1876, Monog. Brit. Aphides, v. 1, p. 114–119, pl. 6.
Nectarophora granaria Oestl., 1887, *in* Geol. and Nat. Hist. Survey Minn. Bul. 4, p. 82.
Macrosiphum granarium Schout., 1901, *in* Ann. Soc. Ent. Belg., t. 45, p. 113–117.
Macrosiphum avenivorum Kirkaldy, 1905, *in* Entomologist, v. 38, p. 132.

DISTRIBUTION IN THE UNITED STATES

M. granarium undoubtedly occurs throughout the United States wherever the small grains are cultivated. The map (fig. 1) indicates localities from which the Bureau of Entomology has records of occurrence. It will be noted that there are 10 States from which the Bureau has no records, though *M. granarium* undoubtedly occurs in those States.

FOOD PLANTS OF THE APHID

This aphid does not confine itself exclusively to its well-known host plants, the small grains, but will live and thrive on a number of the wild and cultivated grasses.

Riley (9) listed *Agrostis vulgaris* [*alba*], *Bromus secalinus*, *Dactylis glomerata*, and *Poa pratensis* as host plants. Besides the plants just

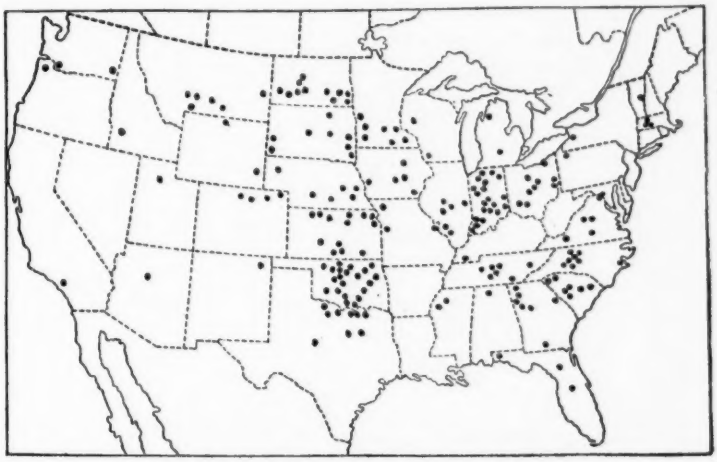


FIG. 1.—Map showing the distribution of *Macrosiphum granarium* in the United States as indicated by records on file in the Bureau of Entomology, 1916.

mentioned, the late F. M. Webster recorded it, in notes on file in the Bureau of Entomology, as breeding on heads of timothy (*Phleum pratense*) at Mitchell and La Fayette, Ind., in 1889, and in 1890 he recorded it as feeding on corn (*Zea mays*) at La Fayette, Ind. In 1904 Pergande (11) recorded *Elymus* sp. as a host.

A series of experiments conducted at La Fayette, Ind., in 1909, showed that *M. granarium* will breed and thrive in confinement upon the following grasses: *Bromus commutatus* (?) [*racemosus*], *B. secalinus*, *Elymus* sp., *Festuca duriuscula* [*ovina*], *F. heterophylla*, *F. pratensis* [*elatior*], *F. tectorum*, *Juncus tenuis*, *Lolium italicum*, *Poa compressa*, and *P. pratensis*. *M. granarium* was found to breed freely in confinement upon *Eleusine indica* and foxtail (probably *Chaetochloa glauca*) at Richmond,

Ind., in 1908. Most of the grasses in the experiments at La Fayette, Ind., were obtained from the experimental plots of the Purdue Experiment Station.

Other members of the Office of Cereal and Forage Insect Investigations have recorded the following hosts: *Bursa bursa-pastoris*, Nashville, Tenn. (G. G. Ainslie); *Syntherisma sanguinale*, North Vernon, Ind., 1908; *Echinochloa crus-galli*, Princeton, Ind., 1908; and *Hordeum pusillum*, Salisbury, N. C., 1909 (R. A. Vickery).

DESCRIPTIONS OF THE FORMS

STEM MOTHER

A number of stem mothers were secured at La Fayette, Ind., in the spring of 1911; but as the writer was absent at the time, the description was written by Mr. J. J. Davis. There was some slight variation in color of the adults, some having a somewhat yellowish tinge.

Body, including thorax, slightly darker than apple green on the dorsum; venter very slightly pruinose, giving it a silvery or whitish color. Eyes dark red. Head pale brownish. Antennæ (Pl. 34, F): I and II concolorous with head, but with slight duskiness; III, IV, V, and VI black. Beak pale brownish at base and the last two segments black. Tip of beak just reaching second coxæ. Legs: Basal half of femora pale greenish, distal half dusky to black; tibiæ pale, with slight brownish tint, the distal end black; tarsi black. Cornicles black; style pale whitish, with slight greenish tint.

Measurements made from four individuals immediately after mounting in balsam:

Length of body.	With style.	Width.
Mm.	*Mm.*	*Mm.*
2. 27	2. 59	1. 21
2. 63	3. 02	1. 47
2. 39	2. 39	1. 12
2. 22	2. 50	1. 24

Cornicles, 0.39, 0.515, 0.408, and 0.51 mm., respectively. The antennal measurements are given in Table I.

TABLE I.—*Length (in millimeters) of antennæ of the stem mothers of Macrosiphum granarium*

No.	Specimen No.						
	1	2	3	4	5	6	7
I	0. 106	0. 106	0. 12	0. 11	0. 10	0. 155	0. 155
II	. 07	. 07	. 08	. 07	. 066	. 06	. 06
III	. 43	. 44	. 53	. 53	. 435	. 586	. 586
IV	. 195	. 185	. 30	. 28	. 15	. 31	. 30
V	. 24	. 23	. 28	. 30	. 23	. 337	. 337
VI base	. 11	. 12	. 12	. 13	. 12	. 14	. 14
VI filament	. 31	. 34	. 34	. 39	. 32	. 42	. 44
Total	1. 571	1. 491	1. 77	1. 81	1. 421	2. 008	2. 018

SUMMER FORMS

The following description is taken from Pergande (11):

Apterous female. [Pl. B, 2.] Length 2.4 to 2.8 mm.; fusiform, broadest near the base of the abdomen. Frontal tubercles large, diverging at the apex, as usual, in this genus; antennæ bristle-shaped, as long or slightly longer than the abdomen; joint six, including the spur, longer than joint three; generally there are one or two small, circular and projecting sensoria near the base of the third joint; all of the joints are very sparsely beset with short and stiff bristles which are rarely slightly clavate. The nectaries are long and reach beyond the tip of the abdomen, though rarely beyond the tip of the tail; they are cylindrical, tapering, becoming again slightly stouter toward the end. The tail is rather long and stout, curved upward, and about two-thirds the length of the nectaries, lanceolate, and more or less distinctly constricted about the middle; it is densely covered with acute, minute points and furnished each side of its terminal half with three, backward-curved, long bristles. The legs are long and provided with short, stiff, and simple hairs.

The color of the apterous female is yellowish-green, often slightly pruinose; frequently darker toward the end of the body; the head varying from yellow to brownish-yellow. The eyes are red to brown, while the tail varies from white to a distinct yellow. The antennæ, as a rule, are black, though sometimes the first joint may be yellow or the first three joints dusky. The terminal half or more of the femora, apex of the tibiæ, the tarsi, and the nectaries brown to black; the rest of the leg is yellow. The body is frequently marked with a brownish puncture or spot each side of the prothorax; sometimes there is a narrow dusky or black line, composed of minute spots, each side of the mesothorax and a dorso-lateral row of about five linear or rounded, blackish or dusky spots each side of the abdomen, which sometimes are extremely faint or even wanting. Occasionally there are also two additional small black or dusky spots between the nectaries. Lateral spots in front of nectaries black.

Winged migrant. [Pl. 33, A.] Expanse of wings 9 to 9.4 mm.; length of body 1.4 to 2.6 mm. Antennæ long, generally about one-third longer than the body; the third joint about one-third shorter than the sixth and provided along its exterior or posterior edge with from six to eleven more or less elevated, round sensoria along its basal third. The hairs of the various joints are similar to those of the apterous female, though sometimes one or the other may be distinctly clavate. The nectaries, tail, and legs in general appearance and size are very similar to those of the apterous form. The wings are almost twice the length of the body, while the venation corresponds very much to that of Aphis.

Color yellowish green to green; the mesothorax yellow and its lobes brown to black. Sometimes a small, oblique, dusky, subdorsal spot and a transverse pale dusky band may be observed on the prothorax. Head brown or brownish-yellow; eyes red to brown. Antennæ black, the first joint sometimes brownish-yellow externally. Nectaries black, the tail yellowish or greenish-yellow; sternal plate and lateral spot in front of wings black. The abdomen is marked with four or five small, transverse, blackish dorso-lateral spots and four black lateral spots in front of nectaries; the coloration of the legs is similar to that of the apterous female. Wings clear, the costa dusky, and the subcosta yellow; stigma yellowish, its inner margin dusky; veins yellowish-brown, changing to black toward the end.

It is probably well to state in this connection that the maculation of the abdomen is quite a variable character and that the cornicles are reticulate at the tip.

The following measurements (Table II) were made from specimens that had been mounted in balsam for over a year.

TABLE II.—*Length (in millimeters) of the antennæ of summer forms of Macrosiphum granarium*

WINGED VIVIPAROUS FEMALES (PL. 34, B)

No.	Specimen No.						
	1	2	3	4	5	6	7
I	0.09653	0.09653	0.09653	0.09653	0.09653	0.09653	.....
II	.06895	.06895	.06895	.07584	.06895	.08274	.....
III	.66192	.60676	.66192	.64813	.59986	.63434	.....
IV	.55849	.55849	.57128	.56539	.47575	.46886	.....
V	.38612	.38612	.44128	.44128	.38612	.35854	.....
VI	.12411	.13100	.12411	.13790	.12411	.11721	.....
	.77224	.....	.66192	.64813	.75845	.64813	.....
Total	2.66836	.....	2.62594	2.61320	2.50977	2.40635	.....
Cornicles	.42749	.....	.43438	.....	.37233	.....	.....
	.41370	.....	.44128	.....	.38612	.....	.....
Cauda	.30338	.....	.30338	.....	.27580	.....	.....

WINGLESS VIVIPAROUS FEMALES (PL. 34, D)

I	0.10342	0.11032	0.11032	0.11032	0.11032	.....	.....
II	.06895	.07584	.07584	.08274	.08274	.....	.....
III	.57918	.75228	.56539	.71708	.68950	0.62055	0.62055
IV	.35854	.35854	.42438	.52402	.52402	.42749	.44128
V	.31027	.28959	.33785	.37233	.38612	.31717	.33096
VI	.11712	.12411	.13790	.12411	.12411	.12411	.12411
	.56539	.53091	.68260	.70329	.68950	.60676	.62055
Total	2.00296	2.06159	2.33428	2.63389	2.60631	.....	.....
Cornicles	.....	.42749	.46196	.....	.59297	.....	.46886
	.....	.42749	.44817	.....	.59297	.....	.48265
Cauda	.....	.33096	.33096	.....	.41370	.....	.34475

SEXES

The following description of the sexes is from Sanderson (13):

Apterous oviparous female. [Pl. B, 5.] One specimen, 1.9 mm. long by 1 mm. wide; antennæ [Pl. 34, E] 2 mm., segments, 3, 0.50 mm.; 4, 0.35 mm.; 5, 0.30 mm.; 6, 0.10 mm.; 7, 0.50 mm.; cornicle, 0.43 mm.; cauda, 0.21 mm. Somewhat smaller than viviparous form. At first yellow, then turning green and darker green. Head light brown. Distal two-thirds of femora, tip of tibia, tarsi and cornicles black, antennæ black. Conspicuous horizontal black marking in pit of connexivum on either side, these being more or less connected by black lines on the sutures of the first six abdominal segments and coalescing to form a faint but distinct black spot on abdominal segments 4–6. Meta-tibia with numerous pores. [Pl. 34, C.]

Winged male. [Pl. 33, B.] Antennæ [Pl. 34, A] 2.8 mm.; segments, 3, 0.68 mm.; 4, 0.50 mm.; 5, 0.46 mm.; 6, 0.14 mm.; 7, 0.78 mm.; cornicle, 0.14 mm.; cauda, 0.14 mm.; wing 3.35 mm. long. The third antennal segment with 35 to 50 sensoria, the fourth segment with a row of 10 to 12 on basal two-thirds, about 10 large sensoria

on distal two-thirds of fifth segment, and usual large sensoria at tip of sixth and seventh segments. Similar to winged viviparous female, but reddish to reddish brown, with black markings on either side of dorso-meson of abdominal segments, especially on the seventh segment where the marking converges on the meson.

INTERMEDIATE FORM

One individual was found that contained only eggs. Her hind tibiæ were not swollen; nor did they have sensoria. The general color was the same as that of the oviparous female. It is not known whether she produced young previous to being mounted.

EGG

The egg is elliptical, 0.3 mm. in diameter and 0.7 mm. long. It is a pale yellow when first deposited, changing in a few days through different shades of green to black.

LIFE HISTORY AND HABITS

Eggs begin to hatch during the last week in March in the latitude of La Fayette, Ind., and continue hatching through the first week in April.

Eggs were obtained in Richmond, Ind., in the fall of 1908, but none hatched the following spring. Eggs were again secured in the fall of 1909 at LaFayette, Ind., though only one hatched from this lot. The mortality of the eggs is very high, but no definite cause can be assigned for this at present. The eggs of this species were placed in hibernation under apparently the same conditions as those of several other species of Aphididae, the latter hatching readily and *M. granarium* hatching very sparingly or not at all. From hundreds of eggs secured in the fall of 1910 only about 15 or 20 hatched. The eggs would remain plump until about time to hatch and would then shrivel. Eggs began hatching on March 24 in 1911.

As is common with Aphididae in general in this latitude, this species at La Fayette, Ind., reproduces parthenogenetically until October, when the sexes appear and eggs are deposited. The writer took adult males in the field on bluegrass at La Fayette in November, 1909, and young males were observed on rye and volunteer oats on the Purdue University farm in November, 1911. No oviparous females have been observed in the fields as yet, but the presence of the males indicates that the sexes occur normally on the small grains and on blue grass in the fall.

Mr. R. A. Vickery, of the Bureau of Entomology, stated that he has taken the sexes on wheat in Minnesota, but he made no mention of having obtained eggs or stem mothers. Sanderson (13) reared adults of both sexes indoors in Texas in 1903, although he made no record relative to the egg. It is doubtful whether eggs occur normally that far south.

Viviparous females have been carried through the winter out of doors in breeding cages at La Fayette, Ind., and at Charlottesville, Va., and have been found on the small grains throughout the fall, in the winter, and again in the early spring, so they doubtless pass the winter both in the egg and as viviparous females in the Northern States. It is doubtful whether eggs and stem mothers normally occur much south of latitude 35° unless it is in higher altitudes.

The aphids remain on the leaves of wheat and other small grains until the heads are formed and then cluster around the tender kernels, sucking the rich sap. Just before harvest, when the plant tissues become hard and tough, all immature individuals become winged and migrate to some of the grasses, where they remain until volunteer grain and fall wheat put in their appearance.

REARING CAGES

The same type of shelter and rearing cages were used as those previously described and figured by the writer (14).

GENERATION SERIES

The generation series were not started with stem mothers in any instance, as no eggs hatched until the spring of 1911. Since they had been carried through consecutive generation series for each of the three preceding years, it was thought unnecessary to continue longer. The series were started each year with the progeny of individuals that had survived the winter. In fact, they were started at the time the eggs of *Toxoptera graminum* began to hatch. It was found later that this was approximately the date of hatching for *M. granarium*.

The usual method that has been followed in the past by the Office of Cereal and Forage Insect Investigations in the generation rearing was adopted for this species—that is, the first born from each first born and the last born from each last born were isolated and daily records made as far as possible. Two partial generation series were carried through in 1907 and four complete ones in 1908 at Richmond, Ind.—that is, they were run either until the sexes appeared in the fall or until the work was interrupted by cold weather. Another generation series was carried through at La Fayette, Ind., in 1909 and one in 1915 at Charlottesville, Va. The writer thus has observations covering nearly 120 individuals. This is a comparatively small number, but since the observations cover practically four years the data should prove reliable.

Tables III and IV give in detail consecutive generations from one individual hatched March 27, 1908, at Richmond, Ind.

TABLE III.—*Line of generations of Macrosiphum granarium at Richmond, Ind., in 1908*

Date.		Temperature.		First-born generation series.																Last-born generation series.					
		Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.
		°F.	°F.																						
Mar.	27	78	53	[a]B	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Apr.	18	63	55	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	19	70	50	2	B	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	20	68	39	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	21	68	33	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	22	79	35	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	23	79	52	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	24	71	60	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	25	74	61	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	26	80	53	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	27	67	42	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	28	54	38	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	29	46	36	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	30	47	33	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
May	1	56	29	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	2	47	35	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	3	55	37	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	4	50	41	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	5	52	49																							
	6	76	49	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	7	63	41	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	8	49	41	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	9	65	42	4	2	B	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	10	73	44		2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	11	76	45	2	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	12	80	60			0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	13	80	55	3	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	14	84	57																							
	15	85	59	0	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	16	86	52	1	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	17	87	54	2	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	18	77	61	2	[b]D	2	B	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	19	68	54		....	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	20	76	54	....	....		0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	21	79	50	0	....	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	22	81	57	2	....	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	23	83	58	0	....	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	24	85	55	0	....	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	25	92	55	0	....		0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	26	86	66	2	....	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	27	88	57		....		2	B	....	....	....	....	....	....	....	....	....	....	....	....	....	B	....	....	....	....
	28	90	57	0	....	0	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	29	90	62	0	....	0	4	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	30	78	62	0	....	0	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	31	71	55	0	....	D	3	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
June	1	64	43	0	....	....		0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	2	76	43	0	....	....	1	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	3	70	52	0	....	....	2	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	4	82	61	0	....	....		0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	5	84	50	0	....	....	5	0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	6	87	55	0	....	....		0	....	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	7	90	60	0	....	....	1	2	B	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	8	86	64	0	....	....		4	0	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	9	78	64	D	....	....	4	0	0	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	10	77	54	....	....	....	1	2	0	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	11	72	43	....	....	....	0	1	0	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....
	12	82	51	....	....	....	2	0	0	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	13	88	59	....	....	....	2	2	0	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	14	70	58	....	....	....			0	....	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	15	64	45	....	....	....	3	1	2	B	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	16	74	30	....	....	....	2	0	2	0	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	....
	17	82	47	....	....	....	1	2	1	0	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....
	18	90	65	....	....	....	0	0	3	0	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	19	91	66	....	....	....			0	0	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	20	89	65	....	....	....	4	1	8	0	....	....	....	....	....	....	....	....	....	....	....	0	....	....	....	....
	21	89	65	....	....	....	1	0	4	0	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....
	22	91	64	....	....	....	2	D	2	0	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....

TABLE III.—*Line of generations of Macrosiphum granarium at Richmond, Ind., in 1908*—Continued.

Date.	Temperature.		First-born generation series.																	Last-born generation series.					
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.
	°F.	°F.																							
June 23	93	68				2		4	4	B										o					
24	94	67				2		5	6	o										o					
25	79	52								o										o					
26	79	49				o		2	4	o										o					
27	88	48				D				o										o					
28	89	52						1	4	o										o					
29	81	60						2	4	o										o					
30	82	54								o										o					
July 1	89	52						o	2	o										1	B				
2	89	57						1	2	o										o	o				
3	82	64						1	2	2	B									D	o				
4	82	66						o	1	3	o										o				
5	88	60						2	D	4	o										o				
6	91	66						o	...	3	o										o				
7	80	64						o		2	o										o				
8	78	48						D	...	5	o										o				
9	84	47								2	o										o				
10	88	51								2	o										o				
11	91	54								2	2	B									o				
12	95	67								6	1	o									o				
13	92	63										o									4				
14	86	65								6	3	o									3				
15	79	57										o													
16	87	54								2	5	o									1	B			
17	90	66								1	1	o									o	o			
18	84	71										o									o	o			
19	80	60										2	B								D	o			
20	77	59								D	D	2	o									o			
21	75	06										1	o									o			
22	88	57											o									o			
23	93	61										1	o									o			
24	86	66										2	o									o			
25	85	64										2	o									o			
26	87	65										1	o									o			
27	89	66										D	o									o			
28	87	60											o									o			
29	88	62											4	B								o			
30	91	63											o	o								o			
31	91	60											o	o								o			
Aug. 1	86	54											o	o								o			
2	93	53											o	o								o			
3	93	55											D	o								2			
4	93	64												o								o			
5	82	67												1								2			
6	86	58												1	B							o	B		
7	79	69												4	o							D	o		
8	75	55												o	o								o		
9	81	50												2	o								o		
10	82	54												o	o								o		
11	88	55												1	o								o		
12	90	69												2	o								o		
13	80	67												o	o								o		
14	90	60												1	o								o		
15	89	61												o	o								o		
16	95	65												1	o								o		
17	93	67												D	o								o		
18	85	58													4	B							o		
19	95	52													2	o							o		
20	77	56													2	o							o		
21	86	47													o	o							o		
22	86	60													2	o							o		
23	83	53													3	o							2		
24	80	50													2	o							1		
25	83	53													2	o							1		
26	81	54													1	o							o		
27	82	51													3	o							2		
28	84	45													1	o							1		

TABLE III.—*Line of generations of Macrosiphum granarium at Richmond, Ind., in 1980*—Continued.

Date.	Temperature.		First-born generation series.																	Last-born generation series.					
	Maximum.	Minimum.	First generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.	Eighth generation.	Ninth generation.	Tenth generation.	Eleventh generation.	Twelfth generation.	Thirteenth generation.	Fourteenth generation.	Fifteenth generation.	Sixteenth generation.	Seventeenth generation.	Second generation.	Third generation.	Fourth generation.	Fifth generation.	Sixth generation.	Seventh generation.
	°F.	°F.																							
Aug. 29	93	51													1	0							1		
30	93	62													2	1	B						2		
31	95	54													2	1	0						1		
Sept. 1	90	56													0	0	0						0		
2	77	46													2	2	0						0		
3	78	37															0						0		
4	81	48													2	2	0						1		
5	86	50													0	0	0						1	B	
6	89	53													1	0	0						0	0	
7	74	46														0	0						0	0	
8	82	40													2	3	0						0	0	
9	90	44													D	0	0						D	0	
10	93	50														2	0							0	
11	94	51														1	5	B						0	
12	94	54														0	2	0						0	
13	89	57														1	4	0						1	
14	84	49														0	2	0						3	
15	84	56														3	2	0						2	
16	85	52														0	2	0						1	
17	87	50														0	1	0						0	
18	91	48														2	1	0							
19	93	50																0						2	
20	95	50														1	0	0							
21	95	51																0						3	
22	91	51														0	2	0						3	
23	90	53														0	1	0						1	
24	93	53														1	0	0						0	
25	92	51														0	2	0						1	
26	90	57														1	0	0						2	
27	87	54															0	0							
28	76	44														2	0	2						2	
29	53	34															0	0	B						
30	74	33															0	0	0					1	
Oct. 1	62	34														1	0	0	0					0	
2	57	25														1	0	0	0					1	
3	69	27														0	0	2	0					1	
4	79	27														0	0	1	0					0	
5	86	34														0	0		0					0	
6	83	39														0	0	0	0					0	
7	76	42														0	0		0					0	
8	60	41														0	0	2	0					0	
9	60	37														0	0		0					0	
10	65	45														0	0	0	0					0	
11	51	39														0	0	1	0					0	
12	59	25														0	0		0					0	
13	73	26														1	0	0	0					1	
14	74	38														0	0	0	0					0	
15	79	46														0	0	1	0					0	
16	78	42														0	0		0					0	
17	81	39														0	0	2	0					0	
18	84	46														0	0	0	0						
19	75	47														0	D	0	0					1	B
20	77	47														0		0	0					0	0
21	79	45														0		0						0	0
22	72	40														0								?	0
23	66	50														0		0							0
24	68	55														0		0							0
25	59	32														0		0							0
26	62	32														D		D							
Total			38	12	16	49	15	40	29	40	12	11	4	12	35	26	24	11	0	10	8	4	13	28	0
Average		19.8																							

[1] The "B" at the head of each column shows that the aphid was born on the date indicated.
[2] The "D" immediately following each column of figures shows that the aphid died on the date indicated. The total number of young for each female is given at the foot of each column.

TABLE IV.—*Line of generations of Macrosiphum granarium at Richmond, Ind., in 1908*

Generation.	Date of birth.	Date of first young.	Age at birth of first young.	Date of last young.	Productive period.	Life after last young.	Number of young.	Average young per day of productive period.	Largest number of young in one day.	Date of death or disappearance.	Total length of life.
First-born generation series:			*Days.*		*Days.*	*Days.*					*Days.*
1	Mar. 27	Apr. 19	23	May 26	37	12	38	1.0+	4	June 9	74
2	Apr. 19	May 9	20	May 17	8	1	12	1.5	2	May 18	29
3	May 9	May 18	9	May 27	9	4	16	1.7+	4	May 31	22
4	May 18	May 27	9	June 25	29	2	49	1.6+	4	June 27	40
5	May 27	June 7	11	June 20	13	2	15	1.1+	2	June 22	26
6	June 7	June 15	8	July 5	20	3	40	2	4	July 8	31
7	June 15	June 23	8	July 4	11	1	29	2.6+	4	July 5	20
8	June 23	July 3	10	July 18	15	1	40	2.6+	5	July 20	27
9	July 3	July 11	8	July 19	8	1	12	1.5	5	...do....	17
10	July 11	July 19	8	July 26	7	1	11	1.5+	2	July 27	16
11	July 19	July 29	10	July 29	1	5	4	4	4	Aug. 3	15
12	July 29	Aug. 6	8	Aug. 17	11	0	12	1.0+	4	Aug. 17	19
13	Aug. 6	Aug. 18	12	Sept. 9	22	0	35	1.5+	4	Sept. 9	34
14	Aug. 18	Aug. 30	12	Oct. 13	44	13	26	.5+	3	Oct. 26	69
15	Aug. 30	Sept. 11	12	Sept. 25	14	24	24	1.0+	5	Oct. 19	50
16	Sept. 11	Sept. 29	18	Oct. 17	19	9	11	.5+	2	Oct. 26	45
17	Sept. 29										
Last-born generation series:											
2	May 27	June 10	14	July 1	21	3	10	.4+	3	July 4	38
3	July 1	July 13	12	July 16	3	3	8	2.6+	4	July 19	18
4	July 16	Aug. 3	18	Aug. 6	3	2	4	1.3+	2	Aug. 8	23
5	Aug. 6	Aug. 23	17	Sept. 5	13	4	13	1	2	Sept. 9	34
6	Sept. 5	Sept. 13	8	Oct. 19	36	3	28	.7+	2	Oct. 22	48
7	Oct. 19										

The other generation series are not tabulated as there do not seem to be sufficiently striking differences to justify it. One generation series ran to 18 in the direct line of first born and to 8 in the last born. Other generation series ran below the one tabulated. One female in the series not tabulated began producing young at the age of 7 days; one female produced 52 young and another lived 79 days. The writer has complete records of the number of young produced by 117 females. They produced 2,333 young, or an average of 19.9+ young each. The average length of time from birth to the production of young for 91 individuals was 12.6+ days. The average productive period for 99 individuals was 16.7 days. The productive period for one female (not in the tabulated series) was 48 days. The average length of life for 89 individuals was 34.3 days.

COLOR VARIATION IN RELATION TO THE SEXES

All who are familiar with this species of Aphididae will probably recall having seen them clustered on heads of wheat just before harvest, and noted distinct variation in color. The majority of them at this time are strongly tinged with pink. There seems to be no satisfactory explanation for the occurrence of the pink forms at this time. The pink forms occur again in October, and this is the signal for the appearance of the

sexes. The writer has taken both pink and green individuals in the summer and kept the progeny of each isolated in rearing cages until fall. The sexes appeared among the descendants from the pink individuals, but very sparingly from the descendants of the green ones. This may not hold in every instance, but it has been the experience of the writer that the sexes can be obtained with certainty by starting with the pink summer forms.

If the cages are examined closely when the sexes begin to appear in the fall, two distinct types of adults will be noted. One is the usual green form (Pl. B, 2) and the other will have a pinkish tinge (Pl. B, 1). If the pink wingless individuals are isolated it will be found that they produce two kinds of young, one slightly tinged with pink (Pl. B, 4) and another a deep pink (Pl. B, 3). The color of the mother after she begins producing young is due in the main to the pinkish young showing through the body wall. The slightly pink individuals are usually produced first. The offspring of the pink wingless individuals usually all become winged, the deep-pink individuals developing to winged males, while the pale-pink winged individuals are viviparous and produce the wingless, yellow, oviparous females (Pl. B, 5). This fact was not known definitely by the writer until the fall of 1909, when he isolated a few pink wingless viviparous females in order to learn what sex their offspring would be. In every case the results were as just stated.

In the fall of 1910 pink wingless individuals were again isolated for observation on their progeny. The results obtained entirely corroborated the data of 1909. In the fall of 1911 a large series was isolated as in 1909 and 1910. A heavy storm accompanied by very low temperatures put an end to the observations before the data were complete, killing all individuals under observation, since the rearing cages offered little natural protection from cold.

Since 1909 and 1910 the writer has found that the winged viviparous females of this series [1] may produce only viviparous individuals in some cases or both oviparous and viviparous, or may produce only the oviparous females. The males are produced only by the wingless pink viviparous females and the oviparous females are produced only by the winged adults that develop from the slightly pinkish young. In other words, the males are sons of the pink viviparous females and the oviparous females are the granddaughters. In no case are oviparous females and males produced by the same mother. The oviparous females might be termed nieces of the males; they are never sisters of the males.

The following outline will illustrate more clearly the sequence of the sexes:

[1] The offspring of the pinkish wingless viviparous females of the autumn forms.

Outlines showing methods of sequence of the autumn forms of Macrosiphum granarium

First method:

- Parental type...
  - Forms of first generation offspring.
    - Pinkish wingless viviparous females.
      - Pinkish nymphs, becoming winged viviparous females.
        - Forms of second generation offspring.
          - Yellow, wingless oviparous females only.
      - Deep-pink nymphs, becoming winged males only.

Second method:

- Parental type...
  - Forms of first generation offspring.
    - Pinkish wingless viviparous females.
      - A. Pinkish nymphs, becoming winged viviparous females.
        - Forms of second generation offspring.
          - a. Yellow, wingless oviparous females only;
          - or
          - b. Wingless viviparous females only;
          - or
          - c. Winged and wingless viviparous females;
          - or
          - d. Yellow, wingless oviparous females and winged and wingless viviparous females.
      - B. Pinkish nymphs, becoming wingless viviparous females.
        - Winged males and winged and wingless viviparous females.
      - C. Deep-pink nymphs, becoming winged males only.

It will be seen, therefore, that in a single cage there may be green, slightly pink, deep-pink, and pale-yellow individuals—quite a wide range in color for a single species.

INFLUENCE OF TEMPERATURE ON PRODUCTION OF SEXES

During the first week in October, 1912, pinkish forms were plentiful in the stock cages and the sexes had begun to appear sparingly. A large number of pinkish individuals that showed promise of producing the sexes were isolated and placed in one of the greenhouses of the Purdue Experiment Station to hasten the production of the sexes and that more data on the progeny of the pink wingless females that appear at this time might be gathered. The greenhouse was kept at a temperature between 50° and 70° F., and the writer thought that since the sexes had begun to appear their numbers could be rapidly increased by placing them in a warmer temperature. Almost the opposite effect was produced. A number of males but only a very few oviparous females appeared. The ones that were obtained were probably born just before or very soon after they were placed in the greenhouse. A stock cage that was left outdoors produced quite a number of oviparous females and

males. This is not conclusive proof, but it certainly indicates that temperatures below 50° F. for a daily minimum in some way exert an influence on the normal production of the sexes.

OCCURRENCE OF THE SEXES AND THE PROPORTION OF MALES TO FEMALES

The first published record on the sexes is by Sanderson (13), who secured them from indoor rearing cages in April. These were the progeny of individuals taken in the fields in January. Notes on file in the Bureau of Entomology show that the late F. M. Webster made observations on the sexes as early as 1884 at Oxford, Ind. He records the males appearing as early as September and females in October and November. Although the egg was observed, no record was made relative to the stem mothers.

These observations in regard to the sexes agree very well with observations made by the writer. The young males first made their appearance during the last week in September or the first week in October. The females usually appear a little later. The males are likely to appear any time during the winter if kept in breeding cages indoors. In rearing cages indoors they appeared sparingly from September to April, inclusive. No oviparous females occurred during the winter. Males undoubtedly outnumber the females from the very fact of their occurrence both in and out of season. During the breeding season (October and November), however, the oviparous females usually outnumber the males, as there are from a fourth to a half as many pink individuals (mothers of oviparous females) as there are males. Each of the slightly pink females may produce from 6 to 20 oviparous females, and that would bring the numbers of the oviparous females far ahead of those of the males.

MATING

Mating occurs sometimes during the first two or three days after the female becomes adult, and oviposition begins in ½ to 5 or 6 days, depending upon the temperature. Females refuse to deposit eggs before mating. If the male is not present the bodies of the females become almost twice the normal size. In one case 5 females were isolated from males for about 10 days or more. Their bodies increased greatly in size, but no eggs were deposited. At the end of that period males were placed in the cage. Mating soon took place. In 10 days there were 13 eggs in the cage but all were infertile.

AGE OF OVIPAROUS FEMALES AT OVIPOSITION

The length of time for maturity of oviparous as for viviparous females depends largely upon temperature. Under the same conditions the oviparous females develop in about the same length of time as the viviparous. Large numbers of both sexes never reach maturity because of

low temperature. One oviparous female became adult in 9 days indoors. Another, born the same day and kept outdoors, developed in 12 days. The age at oviposition, therefore, would be from 14 to 20 days, depending upon the temperature and the presence of the males. The eggs are deposited on the leaves of the plant and on the sides of the cage.

FECUNDITY OF OVIPAROUS FEMALES

The largest number of eggs produced by a single female is 18, the productive period lasting from November 2 to December 1 (1909). Complete records on 20 individuals give an average of 8.4 eggs. The duration of the productive period is from 8 to 29 days.

LENGTH OF LIFE OF THE SEXES

The majority of the oviparous females observed by the writer lived until killed by very low temperatures in November or December. The males do not live quite a month. The female just mentioned, that produced 18 eggs, lived over a month after oviposition began, and was then killed by a severe freeze. Add to this her developmental period and she would be at least 1½ months old. This would probably be high for an average.

MOLTING

Molting experiments have been conducted with each form and it was found that the stem mothers, winged and wingless forms, males, and oviparous females, without exception, molt four times.

NATURAL ENEMIES

APHIDIUS NIGRIPES

The most efficient enemy of *M. granarium* is undoubtedly *Aphidius nigripes* Ashmead. As soon as *A. nigripes* becomes abundant, the brown leather-like, almost circular bodies of the aphids will be noticed firmly attached to the plant. These contain the immature stage of the parasite. Just before harvest, if the infestation of *M. granarium* is heavy, the heads of grain will be almost covered with their brown, dead bodies.

In the fall of 1908 sufficient data were secured to establish the parthenogenetic habits of this parasite. It produces only males under these conditions.

On October 7, 1907, at Richmond, Ind., two virgin females were introduced into a cage with a number of *M. granarium* that had been grown in confinement and had not been parasitized previously. They began oviposition at once. They would approach the aphid cautiously, bend the abdomen under until the tip extended beyond the head, then quickly stab the aphid. There does not seem to be any favorite point of attack, the parasite thrusting at the nearest point. The cage was kept out of doors in the rearing shelter and on November 1 the aphids began to

turn brown. On November 4 they had the usual leather-like appearance and each one was firmly glued to the leaf. On November 23 part of these old bodies were taken indoors and kept at the ordinary room temperature. The temperature went much lower at night than during the day, as the fire was allowed to go out. On December 2, male *A. nigripes* began to emerge and on the 4th all had emerged that were brought indoors. The ones that were left outside were still in the larval stage. This is probably the stage in which they pass the winter.

OTHER INSECT ENEMIES

The late F. M. Webster made more observations on the parasites and predacious enemies of *M. granarium* than any other entomologist. His notes from 1884 to 1890 that are on file in the Bureau of Entomology record the following insects as attacking this aphid:

COLEOPTERA

Podabrus tomentosus Say.
Coccinella 9-notata Herbst.
Hippodamia parenthesis Say.
H. convergens Guérin.
H. 13-punctata Linnaeus.
H. glacialis Fabricius.
Anatis 15-punctata Olivier.
Megilla maculata De Geer.

DIPTERA

Allograpta obliqua Say.
Sphaerophoria cylindrica Say.
Xanthogramma emarginata Say.

HYMENOPTERA

Aphidius avenaphis Fitch.
(*Dioeretus*) *Praon americanus* Ashmead.
(*D.*) *Praon brunneiventris* Ashmead (= *Praon americanus*).
(*D.*) *Praon ferruginipes* Ashmead (= *Praon americanus*).
Isocratus vulgaris Walker.
Encyrtus websteri Howard.
Pachyneuron micans Howard.
Allotria tritici Fitch.

Riley (9) records in addition the following:

COLEOPTERA

Coccinella sanguinea Linnaeus.

DIPTERA

Syrphus americanus Wiedemann.

HYMENOPTERA

Aphidius granariaphis Cook.
Tetrastichus ingratus Howard [*nomen nudum*]
Megaspilus niger Curtis.

All of the parasites listed, however, are not primary. In recent years two species, *Pachyneuron* sp. and *Allotria* sp., have been definitely proved to be secondary parasites. It is very probable that others in the list will be proved secondary upon further study.

FUNGUS ENEMIES

This aphid seems to be very susceptible to fungus attack. During warm, moist weather rearing cages have to be carefully watched or fungus will soon gain control. It undoubtedly destroys many aphids in the fields also.

LITERATURE CITED

(1) KIRBY, William.
1798. History of Tipula tritici, and Ichneumon tipulæ with some observations upon other insects that attend the wheat, in a letter to Thomas Marsham, Esq. *In* Trans. Linn. Soc. [London], v. 4, p. 230–239.

(2) KALTENBACH, J. H.
1843. Monographie der Familien Pflanzenläuse (Phytophthires). 222 p., 1 pl. Aachen.

(3) CURTIS, John.
1845? Observations on the natural history and economy of various insects, etc., affecting the corn crops . . . X. Cecidomyia tritici—the *British* wheat-midge. *In* Jour. Roy. Agr. Soc., England, v. 6, p. 493–518.

(4) WALKER, Francis.
1849. Descriptions of aphides. *In* Ann. and Mag. Nat. Hist., s. 2, v. 3, no. 13, p. 43–53.

(5) KOCH, C. L.
1857. Die Pflanzenläuse Aphiden. 334 p., 54 pl. Nürnberg.

(6) CURTIS, John.
1860. Farm Insects. 528 p., 69 fig., 16 pl. London.

(7) BUCKTON, G. B.
1876. Monograph of the British aphides. v. 1, 193 p., 38 pl. London.

(8) OESTLUND, O. W.
1887. Synopsis of the Aphididæ of Minnesota. *In* Geol. and Nat. Hist. Survey Minn. Bul. 4, 100 p.

(9) RILEY, C. V.
1890. Report of the entomologist. *In* U. S. Dept. Agr. Ann. Rpt., 1889, p. 331–361, pl. 1–6.

(10) SCHOUTEDEN, H.
1901. Le Genre Siphonophora C. *In* Ann. Soc. Ent. Belg., v. 45, no. 4, p. 111–117.

(11) PERGANDE, Theodore.
1904. On some of the aphides affecting grains and grasses of the United States. *In* U. S. Dept. Agr. Div. Ent. [Bul.] 44, p. 5–23, fig. 1–4.

(12) KIRKALDY, G. W.
1905. Current notes. *In* Entomologist, v. 38, no. 504, p. 127–132.

(13) SANDERSON, E. D.
1906. Texas notes—II. *In* Ent. News, v. 17, no. 9, p. 327–328.

(14) PHILLIPS, W. J., and DAVIS, J. J.
1912. Studies on a new species of Toxoptera, with an analytical key to the genus and notes on rearing methods. U. S. Dept. Agr. Bur. Ent. [Bul.] Tech. ser. 25, pt. 1, 16 p., 9 fig., 1 pl.

(15) WEBSTER, F. M., and PHILLIPS, W. J.
1912. The spring grain-aphis or "green bug." U. S. Dept. Agr. Bur. Ent. Bul. 110, 153 p., 48 fig., 9 pl.

PLATE B

Forms of *Macrosiphum granarium:*

1.—Mother of males and grandmother of oviparous females.
2.—Typical green viviparous female.
3.—Pupa of male.
4.—Pupa of the mother of oviparous females.
5.—Oviparous female.

Henry Fox, artist.

Macrosiphum granarium

PLATE B

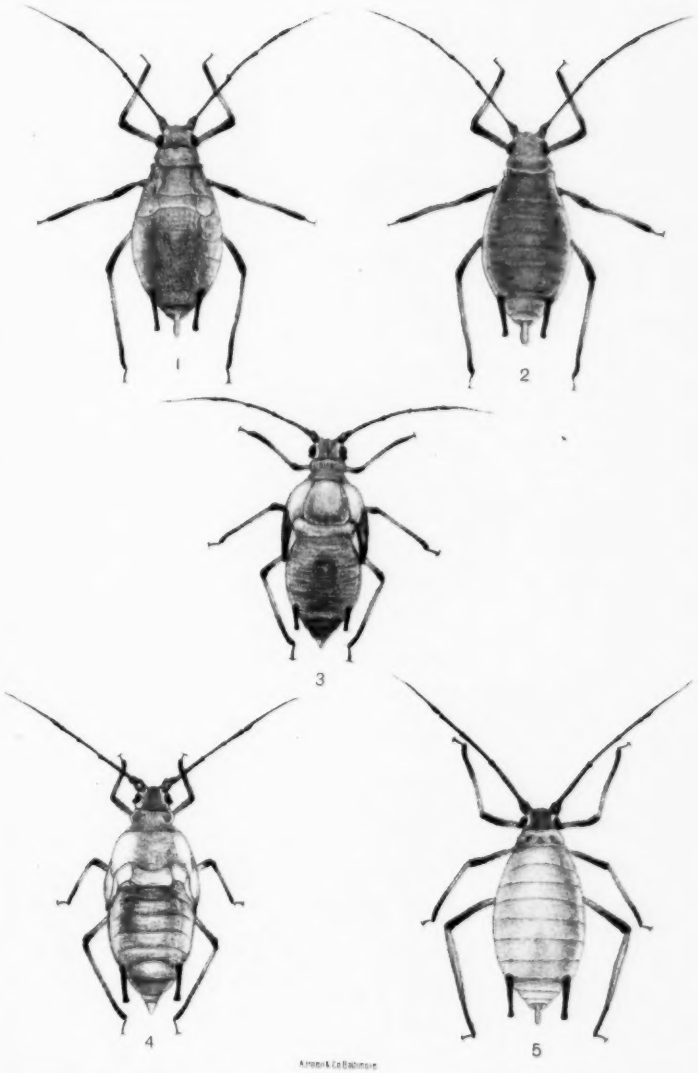
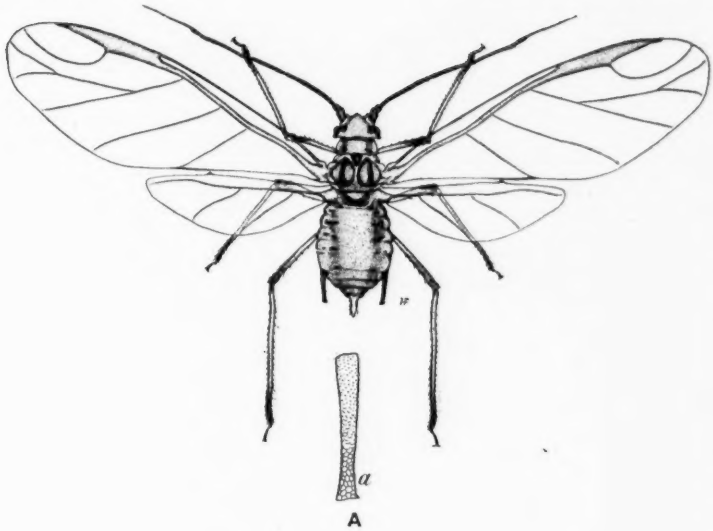


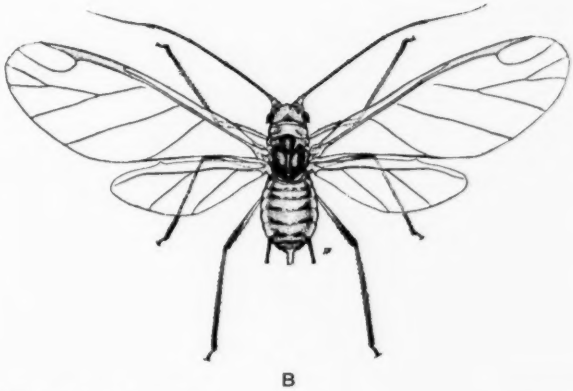
PLATE 33

Macrosiphum granarium:

A.—Winged viviparous female: *a*, cornicle.
B.—Winged male.



A



B

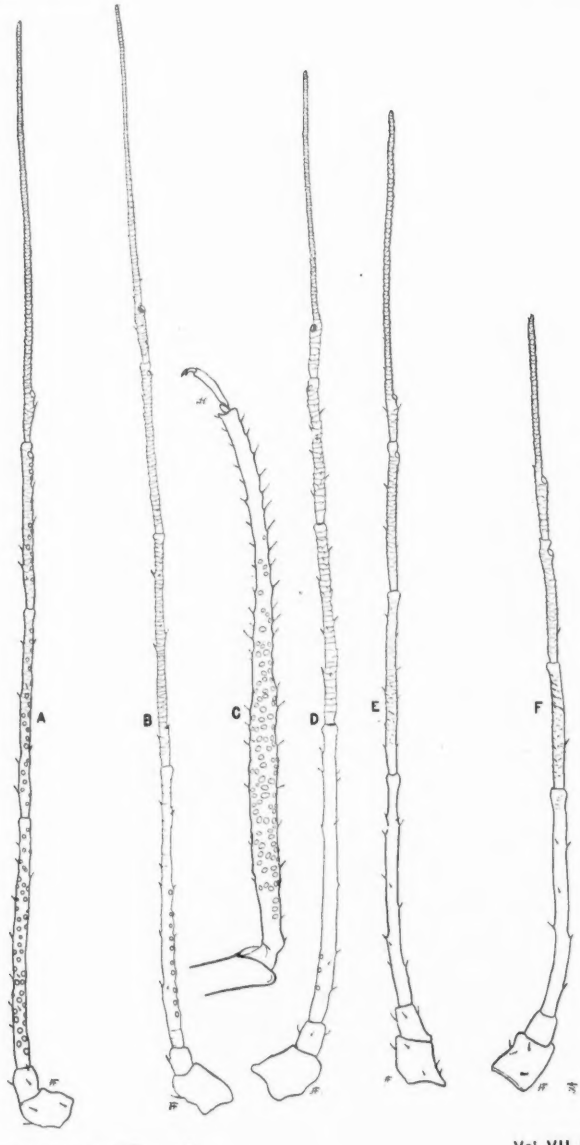

A
B
C
D
E
F

PLATE 34

Macrosiphum granarium:

A.—Antenna of male.
B.—Antenna of winged viviparous female.
C.—Hind tibia of oviparous female.
D.—Antenna of wingless viviparous female.
E.—Antenna of wingless oviparous female.
F.—Antenna of stem mother

A SPECIFIC MOSAIC DISEASE IN NICOTIANA VISCOSUM DISTINCT FROM THE MOSAIC DISEASE OF TOBACCO

By H. A. ALLARD,

Assistant Physiologist, Tobacco and Plant-Nutrition Investigations, Bureau of Plant Industry

During the summer of 1915 many plants of *Nicotiana viscosum* and first-generation plants of the cross *N. tabacum* ♀ × *N. viscosum* ♂ were grown in the field at Arlington, Va. Late in the season three plants of *N. viscosum* and one of the hybrid plants showed unmistakable symptoms of a typical mosaic disease. From the fact that the species viscosum and its hybrids had never before shown symptoms of disease from inoculations made with the virus of the ordinary mosaic disease of tobacco, these affected plants were taken into the greenhouse for further study. It has now been established that this mosaic disease affecting *N. viscosum* and its hybrids is biologically very different from the ordinary form of mosaic disease affecting varieties of *N. tabacum*, tomatoes (*Lycopersicon esculentum*), etc. Ordinary tobacco and also tomatoes appear to be quite immune from the type of mosaic disease in *N. viscosum*. Experiments have shown that this mosaic disease is infectious to plants of *N. viscosum*, although it appears that the disease is not as readily transferred by needle inoculations as the ordinary form of the mosaic disease, and longer periods of time are usually required before the disease comes into evidence.

A number of distinct varieties of *N. tabacum* have been crossed with *N. viscosum*, including Maryland Mammoth, White Burley, and Connecticut Broadleaf. In these crosses the pollen of *N. viscosum* has been transferred to the pistils of *N. tabacum*. In size, general appearance, and habit of growth first-generation plants of these crosses resemble much more closely the female parent (*N. tabacum*) than the male parent (*N. viscosum*). In general appearance the leaves and blossoms also resemble very closely the leaves and blossoms of the female parent. These first-generation plants inherit more strongly the visible physical characteristics of the female parent. They possess, however, certain physiological characteristics peculiar to the male parent (*N. viscosum*). This is indicated by the fact that they, like *N. viscosum*, appear to be immune to that form of mosaic disease which affects varieties of *N. tabacum*, but are susceptible to the mosaic disease affecting *N. viscosum*. The disease is readily obtained in these hybrids by grafting upon them scions taken from plants of *N. viscosum*. It is much more difficult to obtain the disease by needle inoculations. All phases of catacorolla in the blossoms and mottling and distortions in the leaves are shown in these hybrids affected with the

Journal of Agricultural Research,
Dept. of Agriculture, Washington, D. C.
gl

Vol. VII, No. 11
Dec. 11, 1916
G—101

mosaic disease of *N. viscosum* as in ordinary tobacco plants affected with the common form of the mosaic disease (Pls. 35 and 36.) The mosaic disease of *N. viscosum* produces more or less mottling and distortion in the blossoms of these plants. The abnormality known as catacorolla, however, has never appeared in connection with the disease.

TABLE I.—*Inoculations made with the expressed sap of scions of N. viscosum grafted upon ordinary tobacco (N. tabacum)*

Number of plants inoculated (Connecticut Broadleaf).	Date of inoculations.	Material used.	Symptoms of mosaic disease in scion of *N. viscosum*.	Results.
	1915.			
10	Dec. 16	Sap of scion of *N. viscosum* grafted on mosaic stock of *N. tabacum* several weeks.	None.....	All healthy.
10	16	.....do.....	...do.....	3 mosaic.
10	16	Tap water (control).....	.....	All healthy.
	1916.			
10	Jan. 5	Sap of scion of *N. viscosum* grafted upon mosaic stock of *N. tabacum* till scion was in bloom.	None.....	7 mosaic.
10	5	Sap of stock upon which above scion was grafted (symptoms in stock severe).	.....	10 mosaic.
10	5	Sap of scion of *N. viscosum* grafted upon mosaic stock of *N. tabacum* till scion was in bloom.	None.....	2 mosaic.
10	5	Tap water (control).....	.....	All healthy.
10	8	Sap of scion of *N. viscosum* grafted on stock of *N. tabacum* several weeks.	None.....	Do.
10	8	Tap water (control).....	.....	Do.
10	12	Sap of scion of *N. viscosum* grafted several weeks on stock of *N. tabacum*.	None.....	Do.
10	12	.....do.....	...do.....	Do.
10	12	.....do.....	...do.....	Do.
10	29	Sap of scion of *N. viscosum* grafted upon stock of *N. tabacum* till scion was in bloom.	...do.....	Do.
10	29	.....do.....	...do.....	Do.
10	29	.....do.....	...do.....	Do.
10	29	.....do.....	...do.....	Do.
10	29	.....do.....	...do.....	Do.
10	29	Sap of scion of *N. viscosum* grafted upon stock of *N. tabacum* several weeks.	...do.....	Do.
10	29	Tap water and healthy sap.....	.....	Do.

Although the species *N. viscosum* is susceptible to a mosaic disease peculiar to itself, this species of Nicotiana appears to be immune to the ordinary form of mosaic disease affecting *N. tabacum*. Likewise, first-generation plants of the cross *N. tabacum* ♀ × *N. viscosum* ♂ appear to be quite as immune from the disease as the species *N. viscosum*. All

methods of inoculation which have been attempted with these plants have been without success. It has been shown that the virus was not present in these plants by extracting the sap of all parts of the plants and testing its infectivity by making inoculations into young tobacco plants. These inoculations have never produced infection. Furthermore, many successful grafts have been made between *N. tabacum* and *N. viscosum*, using *N. tabacum* as the stock. As soon as the *N. viscosum* scion had started to grow, the stock (*N. tabacum*) was inoculated with the ordinary form of the mosaic disease. Scions of *N. viscosum* in many instances remained upon the mosaic stocks for many weeks and finally blossomed, yet symptoms of the mosaic disease never appeared in the blossoms or leaves. In all instances inoculation tests have been made to determine if the infective principle of the disease was present in the sap of the immune scions. As shown in Table I, these scions in many instances appeared to be entirely free from infection. In other instances the sap proved to be more or less infectious to tobacco plants. Why the sap of the scion should carry the infective principle at one time and not at another can not at present be explained.

The mosaic disease affecting *N. viscosum* appears to be identical in all its symptoms with the mosaic disease of tobacco (*N. tabacum*). The virus of the disease, however, has behaved very differently from the virus of the mosaic disease of tobacco in all inoculation tests. With the exception of *Datura fastuosa* (Golden Queen variety), and *Datura stramonium*, no other plants of the solanaceous family have been found susceptible to the virus of the mosaic disease affecting *N. viscosum*. Although peppers and tomatoes are very susceptible to the virus of the mosaic disease of tobacco, these plants appear to be immune from the virus of the mosaic disease affecting *N. viscosum*, or at least highly resistant to it, since the most persistent and rigorous needle inoculations have failed to produce infection. The most rigorous methods of inoculation have also failed to produce either the mosaic disease of tobacco or the mosaic disease of *N. viscosum* in the Irish potato (*Solanum tuberosum*).

Datura stramonium is the only solanaceous plant which has given evidence of being susceptible to both mosaic diseases. Inoculations made at different times with different lots of virus producing the mosaic disease in *N. tabacum* have given very different results. In some tests the plants were highly resistant to infection. In other tests similar methods of inoculation gave a high percentage of mosaic-diseased plants. It has not been determined whether this variability indicates differences in the infective properties of the virus or differences in the relative resistance of different lots of plants. In one experiment 18 young vigorous plants of *Datura stramonium* were divided into two lots of 9 plants each. One lot was inoculated at many points in the stems and leaves with the virus of the mosaic disease of *N. viscosum*. The remain-

ing 9 plants were inoculated in the same manner with the virus of the mosaic disease of *N. tabacum*. For a period of several weeks numerous inoculations were made from time to time in each lot of plants. The plants of each lot were also cut back severely several times and the virus inoculated into all cut surfaces. The plants were kept under observation for several months. Every plant in the series inoculated with the virus of the mosaic disease of *N. viscosum* developed the disease, the first observable symptoms appearing 21 days after the first inoculation. In this experiment the datura plants proved to be highly resistant to the virus of the mosaic disease of *N. tabacum*, as none became diseased. In those plants affected with the mosaic disease of *N. viscosum* the symptoms were particularly malignant. The leaves became greatly curled, wrinkled, and depauperate. Mottling of the leaves, however, was less marked than in those instances where *Datura stramonium* has been affected with the mosaic disease of *N. tabacum*.

The virus of the mosaic disease affecting *N. viscosum* differs from the virus of the mosaic disease of tobacco as follows:

CHARACTERISTICS OF THE VIRUS OF THE MOSAIC DISEASE OF TOBACCO (N. TABACUM)	CHARACTERISTICS OF THE VIRUS OF THE MOSAIC DISEASE AFFECTING N. VISCOSUM
(1) Transmission through the seed has never occurred.	(1) Transmission through the seed has never occurred.
(2) Incubation period short (minimum 6 days).	(2) Incubation period in *N. viscosum* rather long (minimum may be several weeks).
(3) Needle inoculations readily produce the disease.	(3) Needle inoculation rather uncertain. Grafts of mosaic-diseased shoots of *N. viscosum* upon susceptible plants readily produce infection.
(4) All attempts to infect belladonna (*Atropa belladonna*) and *Solanum tuberosum* have been unsuccessful.	(4) All attempts to infect belladonna and *Solanum tuberosum* have been unsuccessful.
(5) All attempts to infect pokeweed (*Phytolacca decandra*) have been unsuccessful.	(5) All attempts to infect pokeweed have been unsuccessful.
(6) All attempts to infect the hybrid *N. tabacum* ♀ × *N. viscosum* ♂ have been unsuccessful.	(6) The hybrid *N. tabacum* ♀ × *N. viscosum* ♂ is susceptible, manifesting typical symptoms of the disease.
(7) Highly infectious to tomatoes.	(7) All attempts to infect tomatoes have been unsuccessful.
(8) Infectious to the pepper (*Capsicum cerasiforme*).	(8) All attempts to inoculate the pepper have been unsuccessful.
(9) All attempts to infect sweet peas have been unsuccessful.	(9) All attempts to infect sweet peas have been unsuccessful.
(10) All attempts to infect *Datura fastuosa* (Golden Queen variety) have been unsuccessful.	(10) *Datura fastuosa* (Golden Queen variety) is susceptible, manifesting symptoms more or less typical of the disease.
(11) Affects Jimson weed (*Datura stramonium*) producing typical symptoms.	(11) Affects Jimson weed, producing symptoms very similar to those produced

Jimson weed, however, sometimes shows considerable resistance to the mosaic disease affecting *N. tabacum*.

(12) Highly infectious and particularly malignant to *N. rustica*.

by the ordinary mosaic disease of tobacco.

(12) All attempts to infect *N. rustica* have been unsuccessful.

The writer is of the opinion that this distinctive type of mosaic disease affecting *N. viscosum* has in some manner originated from the ordinary form of mosaic disease, possibly through the agency of insect transmission in the field. This does not seem improbable, since practically every susceptible plant in a half-acre field of ordinary tobacco in which the *N. viscosum* plants were grown became mosaic; and throughout the season both species were infested with great numbers of flea beetles. It is possible that insects may become efficient transmitters of disease where ordinary methods of artificial inoculation fail.

During the same season the writer's attention was called to the occurrence of typical symptoms of the mosaic disease in peppers grown in a field near by. To all outward appearances the plants were affected with a severe mosaic disease which gradually spread over the field and persisted in all affected plants. Tomato plants in adjoining rows, however, were unaffected. The expressed sap from the most severely attacked pepper plants failed to produce the mosaic disease in young tobacco plants (*N. tabacum*). Whether this mosaic disease was infectious to healthy pepper plants or might have been in any way related to the mosaic disease affecting *N. viscosum* was not determined.

In this connection it is interesting to note that various European investigators have reported that they were unable to inoculate other species of solanaceous plants with the virus of the mosaic disease of tobacco with which they worked. Thus, Mayer [1] failed to produce the disease in other solanaceous plants.

Iwanowski [2] has stated that the mosaic disease of tobacco does not occur upon *Datura stramonium* or *Hyoscyamus niger*.

Iwanowski,[3] in a later publication, stated that he had never known *Nicotiana rustica* to be affected by the mosaic disease.

Koning [4] also failed to communicate the mosaic disease of tobacco to *Datura stramonium*, *Hyoscyamus niger*, *Solanum tuberosum*, and *Petunia nyctaginifolia*.

Westerdijk,[5] working with a mosaic disease which was infectious to tomatoes, reported that she could not communicate this disease to

[1] Mayer, Adolf. Ueber die Mosaikkrankheit des Tabaks. *In* Landw. Vers. Stat., Bd. 32, p. 450–467, pl. 3. 1886.

[2] Iwanowski, D. Über die Mosaikkrankheit der Tabakspflanze. *In* Bul. Acad. Imp. Sci. St. Petersb., n. s. v. 3 (v. 35), no. 1, p. 67–70. 1892.

[3] Iwanowski, D. Über die Mosaikkrankheit der Tabakspflanze. *In* Centbl. Bakt. [etc.] Abt. 2, Bd. 5, No. 8, p. 250–254, 2 fig. 1899.

[4] Koning, C. J. Der Tabak . . . p. 71–86, fig. 13–15. Amsterdam, 1900.

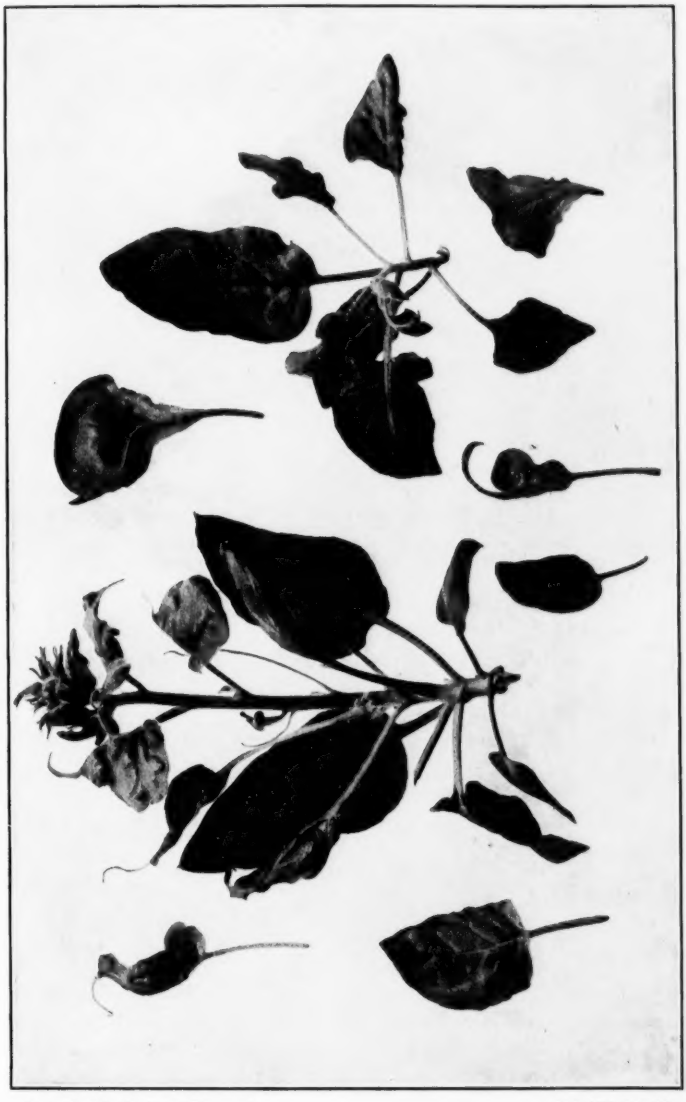
[5] Westerdijk, Johanna. Die Mosaikkrankheit der Tomaten. 19 p., 3 pl. Amsterdam, 1910. [Meded. Phytopath. Lab. "Wille Commelin Scholten." Amsterdam.]

tobacco. Likewise, she could not infect tomato plants with the sap of a mosaic disease of tobacco with which she worked.

The constancy of these negative results is rather striking. It is possible that the type of mosaic disease with which European investigators worked may not have been quite so readily communicable to plants of other species and genera of the solanaceous family as the type in the writer's possession. It has been more or less generally believed in Europe that *N. rustica* was even immune to the mosaic disease affecting tobacco. In the writer's experience the virus of the common form of the mosaic disease is not only very infectious but particularly malignant to plants of *N. rustica*. Likewise, the disease is readily communicable to all the more distinct varieties of tomatoes, petunia, *Datura stramonium*, and is highly infectious to *Hyoscyamus niger*.

PLATE 35

Leaves of *Nicotiana viscosum* affected with the mosaic disease. This mosaic disease does not affect ordinary tobacco (*N. tabacum*); nor does the mosaic disease affecting ordinary tobacco affect *N. viscosum*.



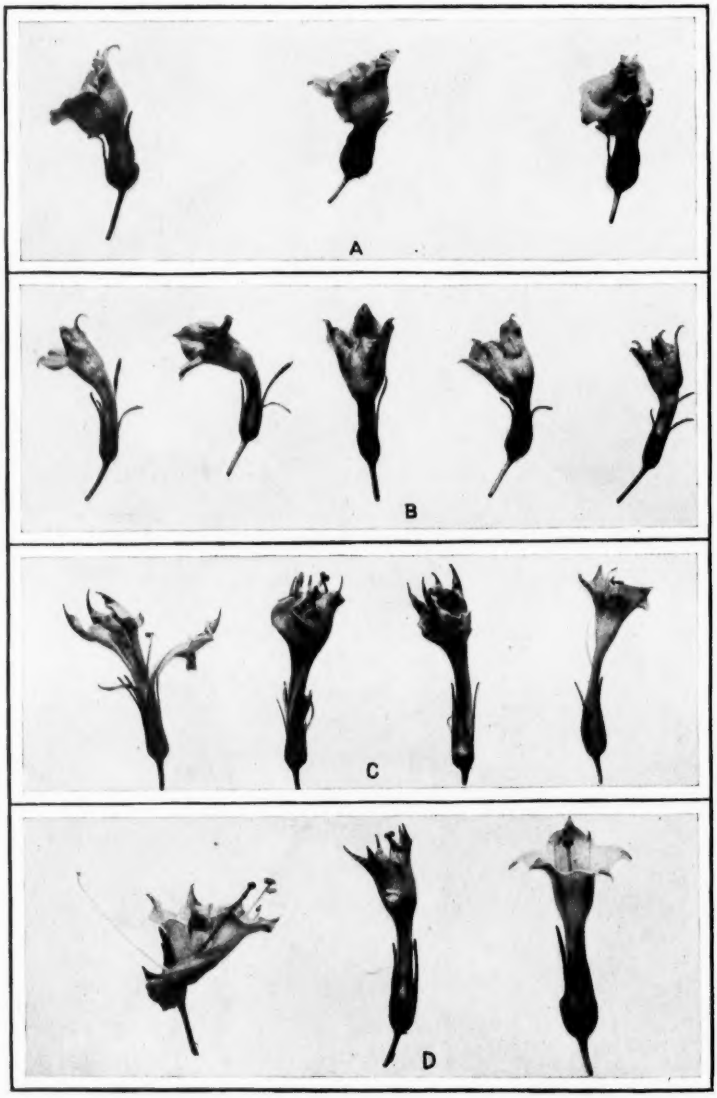

A
B
C
D

PLATE 36

A.—Normal blossoms from healthy plants of *Nicotiana viscosum*.

B.—Depauperate blossoms from mosaic plants affected with the mosaic disease peculiar to *N. viscosum*. This disease is distinct from the ordinary form of the mosaic disease affecting varieties of *N. tabacum* and does not affect them.

C, D.—Blossoms showing catacorolla, etc., as a result of the mosaic disease affecting *Nicotiana viscosum*. These are from first-generation plants of the cross Connecticut Broadleaf tobacco ♀ × *N. viscosum* ♂. This hybrid appears to be immune from the ordinary mosaic disease affecting the female parent, but is susceptible to the mosaic disease affecting the male parent, *N. viscosum*. Although this mosaic disease has never produced instances of catacorolla in *N. viscosum*, all phases of catacorolla are produced in the hybrid. Catacorolla is a common malformation in varieties of *N. tabacum* as a result of the ordinary form of the mosaic disease.

SYNTOMASPIS DRUPARUM, THE APPLE-SEED CHALCID

By R. A. CUSHMAN,

Entomological Assistant, Deciduous Fruit Insect Investigations, Bureau of Entomology

INTRODUCTION

Since the publication by Crosby (7 [1], p. 369) of his paper on the apple-seed chalcid (*Syntomaspis druparum* Boh.) this insect has attracted more and more attention among those associated with the apple industry, and numerous letters relating to it have been received at the Bureau of Entomology. The frequency and wide distribution of these inquiries and complaints seemed to warrant a rather detailed investigation of the insect, and the writer has spent portions of the past two seasons (1914 and 1915) in such an investigation. The biological work was done at the field laboratory for the investigation of deciduous-fruit insects of the Bureau of Entomology at North East, Pa., while the field observations have been conducted throughout the northern tier of States from Vermont to Michigan.

DESCRIPTION OF THE ADULT INSECT

The adult insect is somewhat wasplike in appearance, bright green, with coppery or bronzy metallic reflections, brownish yellow legs, and clear hyalin wings. The female (Pl. 37, A) is normally about 4 mm. in length and is provided with a slender ovipositor slightly longer than the body. The male (Pl. 37, B) is somewhat smaller than the female.

DISTRIBUTION IN THE UNITED STATES

The apple-seed chalcid apparently occurs throughout the northern tier of States, at least from Vermont to Michigan. It has not been found in Ohio or Indiana. At the time of the writer's visit to those States there was a very small crop of apples, and none especially suitable for the attack of the insect were found. But in the same season the chalcid was found in the seeds of a wild seedling at Benton Harbor, Mich. The writer has also found it as far south as Clearfield, Pa., and some years earlier what was almost undoubtedly the larva of this species was found in a crab apple (*Malus* sp.) at Vienna, Va. It is probably distributed throughout the eastern part of the country wherever small seedling apples (*Malus sylvestris*) are to be found.

HISTORICAL REVIEW

Crosby (7, p. 369; 9) has given a nearly complete résumé of the history of the apple-seed chalcid in Europe, where it has been well treated

[1] Reference is made by number to "Literature cited," p. 501.

Journal of Agricultural Research,
Dept. of Agriculture, Washington, D. C.
go

Vol. VII, No. 11
Dec. 11, 1916
K—47

66847°—16——3

recently by Mokrzecki (4). His own papers record the only original observations on the species in America. The insect was first discovered by Prof. Crosby in July, 1906, at Ithaca, N. Y., when he found the seeds of crab apples to contain the partly grown larvæ. His first report of his discovery appeared in 1908 (6, p. 38), and the following year he published his full account (7, p. 369). In the latter paper he summarizes most of the previously published accounts of the species and records in detail his own observations in regard to life history, habits, distribution, and host fruits and gives descriptions of the stages. His 1912 paper (9) consists of further résumés of European literature.

From the wide distribution of the species it is evident that it must have been present though undiscovered in America for a long time, but any statement as to the time of its introduction can be nothing more than speculation. However, that there have been many opportunities for its introduction in the past and that it has been repeatedly introduced in fruit from Europe can not be doubted. It may even have been brought to America before its discovery in Europe, and its establishment here may have been effected at that early time; for it is a historical fact that in the early days of American history apples were imported and their seeds planted by the colonists. Much of the early spread of the apple to the West was due to the Indians, who planted in favorable spots the seeds from apples given them by the settlers. These trees, planted mostly along the trails to the West, would form easy avenues of distribution, and it is quite likely that they and their progeny have aided in the spread of the insect.

EFFECT UPON FRUIT

The only externally visible effect of infestation is caused by the oviposition puncture, which, after a few days, appears as a minute scar situated in a small, shallow dimple. From this scar to the seed extends a discolored line. Under ordinary circumstances of growth and infestation the fruit apparently is able to outgrow both of these manifestations of injury. But occasionally, especially when fruit is scarce or the insects very abundant, the gross injury due to repeated puncturing at nearly the same spot causes permanent and deep dimpling, together with corky, discolored streaks in the flesh. However, even in 1915, when suitable fruit was rather scarce, the season cold, and the chalcids abundant in the region of North East, Pa., such injury was the exception rather than the rule; and in 1914, when the converse of these conditions prevailed, no single case of severe distortion that could be attributed to this species was found. Distorted fruit is shown in Plate 38, A, B, C.

Frequently injury caused by other insects is attributed to the apple-seed chalcid because at the time the injury is noted this species is the only one present. As an example of this, the case of an orchard near Clearfield, Pa., may be cited. The bulk of the fruit in this

orchard in 1914 was very badly distorted, and specimens sent to various entomologists were pronounced to be the work of *Syntomaspis druparum* for the reason that larvæ of this species were found in the seed. The writer visited this orchard in October and examined large numbers of the fruits, but found the chalcid larvæ in comparatively few. Obviously the chalcid was not responsible for such extensive injury, especially in view of the fact that the fruit of wild seedlings almost within the boundaries of the orchard was heavily infested by the chalcid and showed no sign of distortion. Observation in the same orchard the following spring disclosed the fact that it was grossly infested by both species of apple red bugs (*Lygidea mendax* Reut. and *Heterocordylus malinus* Reut.), which had come from *Crataegus* sp. and wild crab in the surrounding woods. These were the insects responsible for the injury to the apples, and the chalcids were able to infest the seeds because of the stunting due to the red-bug injury. It should be stated, in justification of this mistaken determination, that both of the insects concerned are of comparatively recent discovery, and their work is familiar to but few entomologists.

When first infested, the seeds show the laceration caused by the ovipositor surrounded by a brownish area; but as they darken, the injured area heals and ultimately appears as a lighter area, a repeatedly punctured seed having a mottled appearance. At full growth infested seeds are less plump and more irregular than normal seeds. Infested and sound seeds are shown in Plate 39.

Crosby (7, p. 369) states that in the Lady apple the texture of the flesh is considerably injured. This has not been apparent to the writer, for on visiting an orchard containing trees of this variety, from which the owner had picked what he termed an "unusually fine crop," fully two-thirds of the apples examined were heavily infested by the chalcid; but it was impossible to tell whether an apple was infested without examining the seeds or making an almost microscopic examination of the skin for the minute oviposition scars. Special attention was paid to apples of commercial size and color, and a very large percentage was found infested. Moreover, fruit of this variety has been purchased on the Washington market 50 per cent of the seeds of which contained larvæ of the chalcid.

Horvath records failure in Budapest of apple seed to produce a good stand on account of infestation by the chalcid.

VARIETIES AND SPECIES OF FRUIT ATTACKED

The apple-seed chalcid has been found to infest a great variety of fruits. The original description (1, p. 361–362) was based on specimens reared from the seeds of *Sorbus scandica*. The species was redescribed by Thomson (2, p. 76) from seeds of *Sorbus* sp. Rodzianko (5, p. 593–602) reared it from *Sorbus aria*, *Pyrus baccata*, and *Malus sylvestris*. In

Europe it has been mentioned a number of times in connection with the apple, but frequently without any statement as to the nature of the fruit. Porchinsky (3) records the rearing of a species of Torymus from the seeds of wild pear (*Pyrus communis*), but gives no specific determination of the insect. It may have been *Syntomaspis druparum*, but not certainly so. Crosby (7, p. 369) lists the Lady apple, natural fruit, the wild crab (*Pyrus* [*Malus*] *coronaria*), and the following cultivated crab apples: *Pyrus* [*Malus*] *sibricia* var. *striata*, *Pyrus* [*Malus*] *floribunda*, *Pyrus* [*Malus*] *prunifoliae*, and *Pyrus* [*Malus*] *ioensis*. He also states that larvæ, apparently the same, were found in the seeds of *Sorbus latifolia*, but that the adults were not reared. In correspondence with the Bureau of Entomology Mr. M. L. Benn, of Coudersport, Pa., states that he has found infestation by the seed chalcid in Northern Spy, Baldwin, Fameuse, Wagener, Russet, Tolman Sweet, and two seedlings. Mr. G. McL. Stevens, of Orwell, Vt., reported it as attacking Lady apples at Orwell, Vt., and natural fruit at Peru, N. Y., while Mr. A. E. Stene reports it from Kingston, R. I., in the seeds of crab apple.

The writer's observations on the species began a number of years ago at Vienna, Va., where what was undoubtedly the larva of the seed chalcid was found in a seed of a crab apple.

Since the beginning of the work on the species, many varieties of apples have been examined under many conditions and in widely separated localities. At practically every point visited nearly every variety of natural fruit, except the largest, has been found to be more or less generally infested.

Among cultivated varieties the Lady apple only is apparently subject to very serious attack, this variety being frequently very heavily infested. The ordinary commercial varieties are never infested except in neglected and run-down orchards or when fruit is stunted by the overloading of trees or by the attack of some other insect or disease. The reason for the immunity of the ordinary apples of commerce from attack is purely mechanical, in that, at the time the chalcids are ovipositing, such fruit is so large that the ovipositor will not reach to the seeds. However, under the circumstances enumerated above, such varieties are occasionally more or less infested, though never very heavily so. Larvæ have been found by the writer in neglected orchards at North East, Pa., in the following varieties: French Russet, Northern Spy, and Baldwin. In a large orchard near Clearfield, Pa., which in 1914 was very badly infested by red bugs (*Lygidea mendax* Reut. and *Heterocordylus malinus* Reut.), and the fruit much distorted and stunted thereby, only Grimes Golden, Ben Davis, and Missouri of the many varieties examined were infested. Of these Grimes Golden showed about 25 per cent of the fruit infested, from one to four seeds in the infested apples containing larvæ of the chalcid. Of the two other varieties only one apple each was found to be infested.

Crab apples, both cultivated and wild, are very frequently infested, but invariably to a less extent than the small wild seedlings of the true apple, and it is evident that the latter is the natural host of the insect. On one occasion the opportunity offered to compare the infestation in these two classes of fruit where wild crabs and wild seedlings were found growing side by side. Only about 50 per cent of the crabs were infested, and rarely more than one seed to the fruit contained larvæ, while the infestation in the seedling apples was practically 100 per cent, uninfested seeds being scarce.

Although the fruit of the common mountain ash (*Sorbus americana*) has been repeatedly and extensively examined, the writer has never found any trace of infestation by this or any other chalcid.

Neither pears nor the fruit of *Crataegus* sp. exposed to the attack of the chalcid in cages were infested, although attempts at oviposition on the latter were repeatedly observed and many fruits were exposed to attack and later examined.

LIFE HISTORY OF THE CHALCID

The life-history data given below were obtained very largely by propagation of the apple-seed chalcid on wild seedling fruit at North East, Pa., and involved the examination of many hundreds of apples. The female insects were caged on fruit for one day in cages constructed of mica lamp chimneys and cheesecloth (Pl. 40, D).

EMERGENCE IN SPRING

The insects reared in 1914 were from a lot of apples that had been kept in Washington, D. C., during the previous winter and until about May 15, when they were shipped to North East, Pa. The earlier spring of Washington undoubtedly hastened somewhat the emergence of some of the earlier reared adults, for they began to emerge from the seeds on May 26, which was some time before the apples at North East were at the proper stage for oviposition. However, they did not begin to appear in numbers until after the middle of June, the heaviest emergence occurring during the week of June 22–29 and the last on July 5. The adults reared in 1915 were from apples that passed the winter in an unprotected wire cage at North East. The first to emerge appeared on June 16 and the last on July 16, with the heaviest emergence, as in 1914, during about the last week of June.

There appears to be very little, if any, difference in the time of emergence of the sexes. In the more normal emergence of 1915 a few males appeared before any females, and the few belated individuals that emerged after the first few days of July were all females. But during every other day of the emergence season some individuals of each sex appeared.

RELATIVE ABUNDANCE OF SEXES

The rearings during 1914 consisted of 254 females and 85 males, 74.9 and 25.1 per cent, respectively. In 1915, .316 females and 100 males were reared, 75.9 and 24.1 per cent, respectively. These figures show a ratio of about 3 females to each male.

OVIPOSITION

AGE AT BEGINNING.—The female chalcids become mature and able to deposit eggs within a very short time after emergence, for they have been repeatedly observed in the act of oviposition within two days after issuing from the seed.

AGE OF FRUIT.—At the time of the heaviest emergence of the chalcids apples have grown, depending on the variety, to a diameter of from a half inch to somewhat over an inch. The seeds have attained nearly full growth, but have not begun to harden. Most of the space within the seed is occupied by a jelly-like mass, with the small embryo at one end. Between this and the outer seed coat is a rather thick mucilaginous layer.

METHOD AND TIME REQUIRED.—In ovipositing, the female chalcid first feels carefully over the surface of the apple with her antennæ; then, when she has located a place to her liking, she raises the abdomen, at the same time releasing the ovipositor from its sheath and lowering it until its tip is against the surface of the apple directly beneath the posterior end of the thorax. The abdomen is now perpendicular to its normal axis. With pressure accompanied by a slow swinging of the abdomen from side to side the ovipositor is forced slowly into the apple until inserted to its full length. At the end of this time the abdomen has resumed nearly its normal position except that the hypopygidium is directed downward with the ovipositor, making a triangular projection below the abdomen. Now the ovipositor is several times partially withdrawn and thrust back until the insect is apparently satisfied that it has been properly inserted, when she remains perfectly quiet for a considerable period, during which the egg is deposited. When this is finished the ovipositor is withdrawn and swung back into its sheath. The whole process occupies, on the average, somewhat in excess of five minutes. Living chalcids in various phases of the act of oviposition are shown in Plate 40, B, C, while in A one is shown attempting oviposition in the fruit of *Crataegus* sp.

POINT OF ATTACK.—When oviposition first begins, most of the punctures are made around the middle of the apple, but later in the season the attack is shifted nearer to the calyx end. This is apparently made necessary by the fact that the growth of the apples makes it impossible for the ovipositor to reach the seed from the side. Figure 1 shows the position of punctures in fruit and seed.

RELATION BETWEEN PUNCTURES MADE AND EGGS DEPOSITED.—That the instinct of the ovipositing female in locating the seed is not so strong and unerring as might at first be supposed, when the frequent very high percentage of infestation of the seeds is considered, is indicated by the number of punctures made in the seed compared with the number showing on the surface of the apple. The puncture is much more conspicuous on the white seed than on the skin of the apple; yet one fruit that had been punctured 36 times had only five punctures on its seeds. It is unlikely that each puncture made represents an egg deposited, but rather that many punctures represent unsuccessful attempts at finding seed. This is borne out by the observations on ovipositing females, which frequently inserted their ovipositors repeatedly at almost the same point before ultimately going through all the phases of the act of oviposition. It is not even probable that every puncture in the seed represents the deposition of an egg. No definite assertion on this point can be made, since the eggs are rather difficult to find.

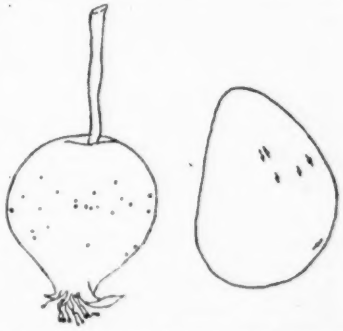


FIG. 1.—*Syntomaspis druparum:* Apple, natural size, and seed, enlarged, showing oviposition punctures. (Original.)

PLACE OF DEPOSITION OF EGG.—Apparently it is the aim of the insect to place its egg in the central gelatinous mass of the seed, and from the position of many of the punctures it is impossible that through them the ovipositor could have reached this body. Many punctures are on the side of the seed, in such position that the ovipositor must have been nearly tangent to the surface of the seed.

Sometimes eggs are deposited in the mucilaginous layer next to the seed coat, but the resulting larvæ apparently never mature, for many dead larvæ of the first instar have been found in this situation, and living larvæ found there have always been in the first instar and far behind, in growth, the larvæ of the same age in the more favorable jelly-like body.

OVIPOSITION PERIOD.—The longest period during which any of the caged females were ovipositing in 1914 was from June 25 to July 21, a period of 26 days, two insects in the same cage having died on the same date. During this time 48 apples were exposed, and all were more or less infested. Others lived for periods ranging from 3 to 24 days, the quicker deaths being due apparently to the sun striking the cages.

EGG

DESCRIPTION.—The egg (fig. 2) is elongate oval, roundly pointed at the caudal end, and prolonged at the cephalic end into a slender, twisted pedicle about one-fourth the diameter and nearly as long as the body

of the egg. Exclusive of this appendage, the egg is about 0.55 mm. in length by about a fourth as thick in the middle. It is yellowish white and without sculpture. Within two days after oviposition the embryo can be seen to have drawn away from the poles, and in some the cephalic constriction can be seen.

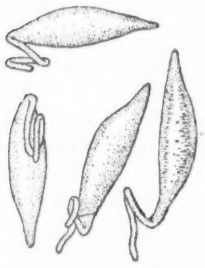


FIG. 2.—*Syntomaspis druparum:* Eggs. Highly magnified. (Original.)

INCUBATION PERIOD.—In 1914 the eggs began to hatch on the sixth day after deposition, and by the eighth day all had hatched. In 1915 hatching commenced on the seventh day and continued until the tenth day.

LARVA

NUMBER AND DESCRIPTION OF INSTARS.—The newly hatched larva (fig. 3) is about 0.4 mm. in length by about a fourth as thick at the thickest point, which is at the junction of the thoracic and abdominal segments. From this point it tapers in both directions, but is much smaller at the caudal end. The body, including the head, consists of 14 segments; the 3 thoracic segments are about equal in length, and the abdominal segments gradually decrease in length toward the caudal end. The head is nearly hemispherical and rather heavily chitinized. The mouth opening is nearly circular and surrounded by a raised rim. Owing to the minute size and delicacy of the mouth parts, except the strong mandibles, it is difficult to determine definitely their exact relation to each other, but they appear to be about as in the illustration (fig. 4). The mandibles are long, strongly curved, and dark colored. They cross in the middle of the mouth opening. The head is from 0.108 to 0.123 mm. in breadth and the mandibles 0.021 mm. in length. At full growth the larva of the first instar is slightly less than 1 mm. in length.

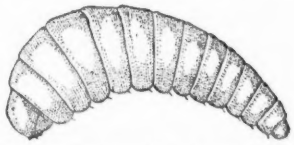


FIG. 3.—*Syntomaspis druparum:* Newly hatched larva. Highly magnified. (Original.)

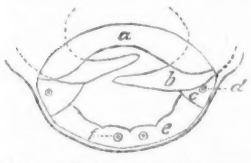


FIG. 4.—*Syntomaspis druparum:* Mouth parts of larva of first instar. *a*, Labrum; *b*, mandible; *c*, maxilla; *d*, maxillary palpus; *e*, labium; *f*, labial palpus. Highly magnified. (Original.)

The larva of the second instar is very similar in general appearance to that of the first instar, having the same tapering form though being somewhat stouter. It can, however, be easily distinguished by the weaker chitinization of the oral region and the change in the form of the mandibles, which at this molt assume a form more similar to those of the full-grown larva. The brown color of the mandibles is confined to their tips, and they are very stout at the base and much less strongly curved (fig. 5, *a*). The head in this instar is from 0.184 to 0.215 mm. broad,

and the mandibles from 0.036 to 0.039 mm. long. At full growth the second instar is about 1.5 mm. long.

With each succeeding molt the larva becomes gradually stouter and less tapering behind until at full growth it is more than a third as thick as long, with the caudal end but little more tapering than the head end, and the head becomes relatively smaller and more retracted within the thorax. With each molt the head and mandibles increase markedly in size, and the latter change somewhat in form. These changes in measurements and form constitute the only real differentiating characters until in the last instar the spiracles become open and visible.

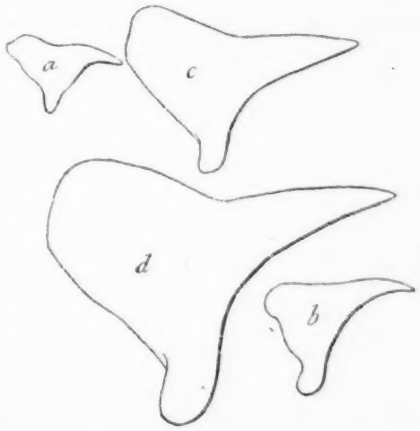


FIG. 5.—*Syntomaspis druparum:* Mandibles of larvæ of various instars. *a*, Second; *b*, third; *c*, fourth; *d*, fifth. Highly magnified. (Original.)

The head of the third-instar larva varies in breadth from 0.277 to 0.308 mm. and the length of the mandibles from 0.050 to 0.057 mm. The latter (fig. 5, *b*) are curved toward the apex. In the fourth instar the head is from 0.415 to 0.461 mm. broad and the mandibles (fig. 5, *c*) 0.079 to 0.086 mm. long and nearly straight at the apex.

The full-grown or fifth-instar larva (fig. 6) is of the typical chalcid form, rather spindle-shaped but somewhat curved toward the ventral side, with the head short and flattened and partially retracted within the first thoracic segment. The mesothoracic and metathoracic segments and the first seven segments of the abdomen bears each a pair of minute spiracles. Fully fed larvæ are mostly from 4.5 to 5 mm. long, but a few, which develop in small seeds, are much smaller, the smallest measured being 3 mm. in length. The head is from 0.554 to 0.6 mm. broad and the mandible (fig. 5, *d*), the blade of which is rather slender and nearly straight, is from 0.111 to 0.129 mm. long. The arrangement of the mouth parts is shown in figure 7.

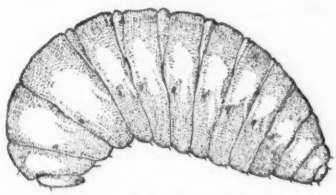


FIG. 6.—*Syntomaspis druparum:* Full-grown larva. Much enlarged. (Original.)

PLACE OF FEEDING.—The earlier feeding of the larva is done in the gelatinous portion of the developing seed. In the meantime the embryo is developing and the gelatinous body is being absorbed. Before the

latter entirely disappears the larva begins to feed on the cotyledons, eating out a pit on one edge or one side and ultimately devouring the last traces of the embryo.

DURATION OF INSTARS AND FEEDING PERIOD.—The two seasons during which observations on the life history of the apple-seed chalcid were made were quite different, and the development of the larvæ was consequently quite different in point of time required. The summer of 1915 was unusually cold, and the larvæ required about a week longer to complete their development than those of 1914.

The observations of 1914 were complicated and rendered somewhat difficult of interpretation because of an unexpected infestation from natural sources. The presence of the species in the locality was not discovered until too late to escape the infestation from that source. However, the natural infestation was, as a rule, either considerably earlier or considerably later than that in the cages, and some information of value can be secured from the data obtained.

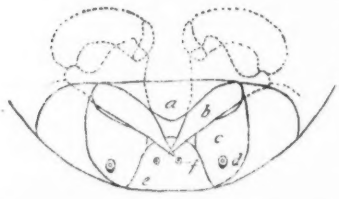


FIG. 7.—*Syntomaspis druparum:* Mouth parts of full-grown larva. *a*, Labrum; *b*, mandible; *c*, maxilla; *d*, maxillary palpus; *e*, labium; *f*, labial palpus. Highly magnified. (Original.)

In 1915 these difficulties were eliminated by the expedient of bagging all fruit to be used in the work both before and after it was exposed to the attack of the insects in the cages.

In 1914 the first individual of each instar was found about four days after the first of the immediately preceding instar, all transformations from one instar to the next taking place within a period of about a week. In about 45 days from oviposition practically all the larvæ had finished feeding. Table I gives the data on the development of the seed chalcid during 1914. From this table are excluded all individuals the presence of which was obviously due to natural infestation.

TABLE I.—*Development of Syntomaspis druparum at North East, Pa., in 1914*

Period from infestation to examination.	Date of infestation.	Date of examination.	Stages of insect found.					
			Eggs.	First larval.	Second larval.	Third larval.	Fourth larval.	Fifth larval.
Days.								
3–4	June 20–21	June 24	6					
4–5	July 3–4	July 8	3					
5–6	June 18–19	June 24	4					
6	June 25	July 1	17		2			
	July 2	July 8	3		3			
	July 9	July 15	2		4			
7	July 1	July 1	1		3			
8	June 23	do			6			
	July 7	July 15			12			
8–9	June 29–30	July 8			3			
9	July 6	July 15			3			
	July 7	July 16			4			

TABLE I.—*Development of Syntomapsis druparum at North East, Pa., in 1914*—Contd.

Period from infestation to examination.	Date of infestation.	Date of examination.	Stages of insect found.					
			Eggs.	First larval.	Second larval.	Third larval.	Fourth larval.	Fifth larval.
Days.								
8–10	July 12–14	July 22		1				
10	July 6	July 16		1				
10–11	June 18–19	June 29		17				
	June 27–28	July 8		8				
11	July 5	July 16		2	4			
12	June 26	July 8		8				
12–13	July 3–4	July 16		1	3			
13	June 24	July 8		12	5			
	July 9	July 22			3			
14	June 24	July 8		3	5			
	July 2	July 16			2	1		
	July 8	July 22			3	2		
15	June 23	July 8			4			
16	June 22	do			1	3		
17	July 5	July 22				9		
17–18	June 20–21	July 8			1	7		
18	June 23	July 11				3	15	
18–19	June 27–28	July 16				4	4	
	July 3–4	July 22				2	3	
19	June 22	July 11				3	12	
20	June 26	July 16				2	3	
	July 2	July 22					7	
22	June 24	July 16					4	1
23	June 23	do					6	2
24	June 22	do					6	4
24–25	June 27–28	July 22					2	1
25–26	June 20–21	July 16					7	10
26	June 26	July 22						4
27	June 25	do						6
29	June 23	do						6
31	June 22	July 23						4
32–33	June 20–21	do						4
38–39	do	July 29						2
40–41	June 18–19	do						1

In 1915 the earliest hatching took place on the seventh day after oviposition, the earliest first molt on the sixteenth day, the earliest second molt on the twenty-first day, the earliest third molt on the twenty-fifth day, and the earliest last molt on the twenty-ninth day, and the first larva to consume the entire seed contents had done so on the forty-ninth day. The last larva to finish feeding required 57 days.

Table II shows all the life-history data obtained during 1915 from cage-infested apples. As will be noted, all apples used in this work were infested during a period of 5 days from June 28 to July 2. Thus all individuals were developing under practically identical conditions. It will also be noted that many of the belated first-instar larvæ and eggs were found in the mucilaginous tissue surrounding the central gelatinous body.

TABLE II.—*Development of Syntomaspis druparum at North East, Pa., in 1915*

Period from oviposition to examination.	Date of oviposition.	Date of examination.	Stage and number of individuals found.						Remarks.
			Egg.	First larval.	Second larval.	Third larval.	Fourth larval.	Fifth larval.	
Days.									
6	June 29	July 5	10	.....	.....	.....	.....	.....	
7	June 28	...do.....	.....	3	.....	.....	.....	.....	
7	July 2	July 9	1	.....	.....	.....	.....	.....	
8	July 1	...do.....	6	6	.....	.....	.....	.....	
8	July 2	July 10	1	3	.....	.....	.....	.....	
9	June 28	July 7	1	5	.....	.....	.....	.....	
10	...do.....	July 8	.....	8	.....	.....	.....	.....	
11	...do.....	July 9	.....	7	.....	.....	.....	.....	
12	...do.....	July 10	.....	5	.....	.....	.....	.....	
12	July 2	July 14	.....	11	.....	.....	.....	.....	
13	June 28	July 11	.....	6	.....	.....	.....	.....	
13	July 1	July 14	.....	10	.....	.....	.....	.....	
14	June 28	July 12	.....	2	.....	.....	.....	.....	
15	...do.....	July 13	.....	25	.....	.....	.....	.....	
16	...do.....	July 14	.....	12	3	.....	.....	.....	
17	...do.....	July 15	.....	4	5	.....	.....	.....	
18	...do.....	July 16	.....	3	5	.....	.....	.....	
19	...do.....	July 17	1	6	10	.....	.....	.....	Egg and two first-stage larvæ were in mucilaginous tissue at large end of seed.
19	July 1	July 20	.....	2	3	.....	.....	.....	
20	June 28	July 18	.....	4	5	.....	.....	.....	
21	...do.....	July 19	.....	1	5	2	.....	.....	First-stage larva in mucilaginous tissue.
22	...do.....	July 20	1	1	5	2	.....	.....	Egg and first-stage larva in mucilaginous tissue, seeds considerably hardened.
22	June 29	July 21	.....	1	4	8	.....	.....	First-stage larvæ in mucilaginous tissue.
23	June 28	...do.....	.....	3	.....	6	.....	.....	Do.
24	...do.....	July 22	.....	.....	.....	2	.....	.....	
24	June 29	July 23	.....	.....	2	3	.....	.....	
25	June 28	...do.....	.....	.....	.....	7	2	.....	
26	...do.....	July 24	.....	.....	2	3	3	.....	
27	...do.....	July 25	.....	.....	1	1	6	.....	
28	...do.....	July 26	.....	.....	.....	.....	8	.....	
29	...do.....	July 27	.....	.....	.....	.....	6	.....	
29	July 2	July 31	.....	.....	.....	3	15	4	
30	June 28	July 28	.....	.....	.....	.....	4	.....	
30	July 1	July 31	.....	.....	.....	.....	7	1	
30	July 2	Aug. 1	.....	.....	.....	.....	4	4	
31	July 1	...do.....	.....	.....	.....	.....	8	7	
32	June 29	July 31	.....	1	.....	.....	6	8	First-stage larva in mucilaginous tissue.
32	July 2	Aug. 3	.....	.....	.....	.....	2	7	
33	July 1	...do.....	.....	.....	.....	.....	1	10	
33	July 2	Aug. 4	.....	.....	.....	.....	1	7	
34	July 1	...do.....	.....	.....	.....	.....	3	13	
35	...do.....	Aug. 5	.....	.....	.....	.....	1	13	
36	...do.....	Aug. 6	.....	.....	.....	.....	.....	8	
37	...do.....	Aug. 7	.....	.....	.....	.....	2	9	
38	July 2	Aug. 9	.....	.....	.....	.....	.....	13	
39	July 1	...do.....	.....	.....	.....	.....	1	8	
39	July 2	Aug. 10	.....	.....	.....	.....	3	20	
40	July 1	...do.....	.....	.....	.....	.....	.....	4	
40	July 2	Aug. 11	.....	.....	.....	.....	.....	17	
41	...do.....	Aug. 12	.....	.....	.....	.....	.....	12	
42	June 29	Aug. 10	.....	.....	.....	.....	.....	8	
43	June 28	...do.....	.....	.....	.....	.....	.....	2	
43	June 29	Aug. 11	.....	.....	.....	.....	.....	15	
44	...do.....	Aug. 12	.....	.....	.....	.....	.....	12	
45	...do.....	Aug. 13	.....	.....	.....	.....	1	10	
46	...do.....	Aug. 14	.....	.....	.....	.....	.....	8	
47	...do.....	Aug. 15	.....	.....	.....	.....	.....	11	
48	...do.....	Aug. 16	.....	.....	.....	.....	.....	7	
49	...do.....	Aug. 17	.....	.....	.....	.....	.....	9	[2] had consumed entire seed contents.
50	July 2	Aug. 21	.....	.....	.....	.....	.....	9	
51	...do.....	Aug. 22	.....	.....	.....	.....	.....	7	[3] had consumed entire seed contents.
52	...do.....	Aug. 23	.....	.....	.....	.....	.....	10	Do.
53	...do.....	Aug. 24	.....	.....	.....	.....	.....	8	[4] had consumed entire seed contents.
54	...do.....	Aug. 25	.....	.....	.....	.....	.....	7	[5] had consumed entire seed contents.
55	...do.....	Aug. 26	.....	.....	.....	.....	.....	7	Do.
56	...do.....	Aug. 27	.....	.....	.....	.....	.....	9	[7] had consumed entire seed contents.
57	...do.....	Aug. 28	.....	.....	.....	.....	.....	7	Do.

On August 30, 1915, two days after the last cage-infested apple had been examined, 165 seeds infested naturally were examined to determine whether all larvæ had by that time finished feeding. Of the larvæ found, 132, or exactly 80 per cent, had consumed the entire contents of the seed and the rest had practically done so. Of 50 larvæ examined on September 2, all had finished feeding. In other words, by the last of August all the larvæ had reached full growth.

NUMBER MATURING IN A SINGLE SEED.—In removing larvæ from apple seeds the fact has been observed that as they increase in size and age the likelihood of finding more than one in a seed decreases. It is not at all uncommon to find 6 or 7 very young larvæ in a single seed, even in an apple naturally infested; but on only one occasion has more than 1 of the fifth instar been found within a single seed. In this case there were 2. The number is usually reduced to 1 before the fourth instar is reached. This reduction in number is brought about by the actual killing and eating of the surplus larvæ by the one which ultimately matures. On a number of occasions this cannibalistic habit has been observed, the larvæ concerned being usually in the second or third instar.

HIBERNATING LARVA.—When the larva has consumed its total supply of food it very shortly assumes what may be called the hibernating form (Pl. 38, D). This does not involve a molting of the skin but consists merely in longitudinal contraction of the body, the head and caudal segments being drawn in and the body becoming relatively thicker and more deeply wrinkled. In this condition it remains until the following spring.

BIENNIAL BROOD.—Not all of the larvæ from eggs of a given season finish their development and emerge as adults the following spring, but a large percentage of them remain as larvæ within the seeds until the second spring. This was suspected during the summer of 1914, when, on July 23, the writer, in examining some seeds infested in 1913, found some that still contained living larvæ. One hundred seeds were selected at random to determine roughly what percentage of the larvæ were likely to live over until the next spring. Of these 100 seeds, 54 contained dead larvæ, 26 living larvæ, and from 14 the adult insects had emerged. Of the living insects 65 per cent had not emerged. This lot of seed was kept until the summer of 1915 and count kept of the emerging adults. A total of 416 insects were reared in the second spring as against 339 in 1914. In other words, 55.1 per cent of the insects lived over two winters as larvæ.

It would appear that this curious habit serves to prevent extermination of the species by a season of no fruit.

PUPATION.—The larvæ begin to pupate during the latter half of May, the latest pupation, judging from the emergence of the adults, probably taking place from three weeks to a month later.

PUPA

DESCRIPTION.—The pupa (fig. 8) is normally, depending on the sex, from 3 to 4 mm. long, females being the larger. It is at first white, but later those parts that are chitinized in the adult become first brownish and later dark greenish; this color being really on the body of the adult, developing within the pupal skin and showing through the latter. The legs, wing pads, antennæ, and palpi are folded along the sides and venter, and in the female the ovipositor extends over the back, reaching nearly to the head.

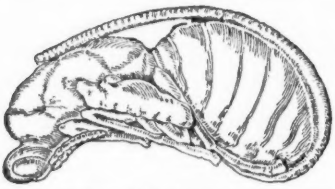


FIG. 8.—*Syntomaspis druparum:* Pupa of female. Much enlarged. (Original.)

PUPAL PERIOD.—The pupal period is of about four weeks' duration, some ndividuals requiring slightly less and some slightly more than this period.

ECONOMIC IMPORTANCE

As has been pointed out on an earlier page, the only commercial fruits that are, under conditions of ordinary care, at all heavily infested by the seed chalcid are the Lady apple and, occasionally, crab apples, both varieties with very limited markets. Also, under normal conditions of growth distortion of fruit to such extent as to render it unmarketable is rather rare, and infestation by the chalcid apparently has no effect on the color of fruit. As pointed out by Crosby and as proven by the observations of the writer, Lady apples are apparently practically immune to the distortion of oviposition. These things being true, it is apparent that economically the seed chalcid is of little importance.

CONTROL OF THE CHALCID

NATURAL CONTROL.—Apparently the apple-seed chalcid has no specific enemies. No records of such are to be found in European or American literature, and none has come under the observation of the writer. Other apple insects, such as the codling moth, which sometimes devour the seeds, undoubtedly destroy a limited number of chalcid larvæ, and others, which feed in the fallen apples, account for the death of a few more. Some adult chalcids doubtless fall prey to birds, spiders, and other predators. But all of these together constitute only a very small measure of control.

Mortality among the hibernating larvæ is apparently very small also; for of 115 larvæ found in apples that had lain under the tree all through the winter of 1914–15 only three were dead, and each of these was in a seed that had been eaten into by some other insect. The mortality in seeds that become separated from the pulp may be higher, but as it is almost impossible to find such seeds no data on the point are available.

ARTIFICIAL CONTROL.—Inasmuch as the seed chalcid attacks normally only varieties that are grown on a very small scale it can be controlled with comparatively little effort by purely mechanical means. In the first place, all wild seedling apples and wild crab apples in the neighborhood of such varieties should be destroyed. This would not only eliminate the outside source of this insect, but also of many other much more serious pests. This should be done in the spring or summer, preferably in August after oviposition has ceased, to insure the destruction of the chalcid larvæ of the season. From the seed crop of the previous season there will still be the chalcids of the biennial brood for the next following season to contend with, but in two years this source of infestation will be entirely eliminated. In addition to the foregoing the careful destruction of all drop fruit and culls for two seasons will practically exterminate the chalcids. If the waste fruit is converted into cider, the pomace should be destroyed.

LITERATURE CITED

(1) BOHEMAN, C. H.
1834. Skandinaviska Pteromaliner. *In* K. Svenska Vetensk. Akad. Handl., 1833, p. 329–380.

(2) THOMPSON, C. G.
1875. Skandinaviens Hymenoptera. Delen 4. Lund.

(3) PORCHINSKII, I. A.
1893. [Torymus bred from pear seeds.] (In Russian.) *In* Horae Soc. Ent., Rosst., t. 27, 1892/93, Bul. Ent., p. ix.

(4) MOKRZECKI, S.
1906. Beitrag zur Kenntnis der Lebensweise von Syntomaspis pubescens Forst., druparum (Boh.) Thoms., (Hymenoptera, Chalcididæ). *In* Ztschr. Wiss. Insektenbiol., Bd. 2, Heft 12, p. 390–392, 2 fig.

(5) RODZIANKO, W. N.
1908. Commentatio de Torymidis, quarum larvæ in seminibus Pomacearum vitam agunt. *In* Bul. Soc. Imp. Nat. Moscou, n. s. t. 21, 1907, p. 592–611.

6) CROSBY, C. R.
1908. Notes on a chalcid (Syntomaspis druparum Boh.) infesting apple seeds. (Abstract.) *In* Ann. Ent. Soc. Amer., v. 1, no. 1, p. 38.

(7) ———
1908. On certain seed-infesting Chalcis flies. N. Y. Cornell Agr. Exp. Sta. Bul. 265, p. 367–388, fig. 73–98, 2 pl.

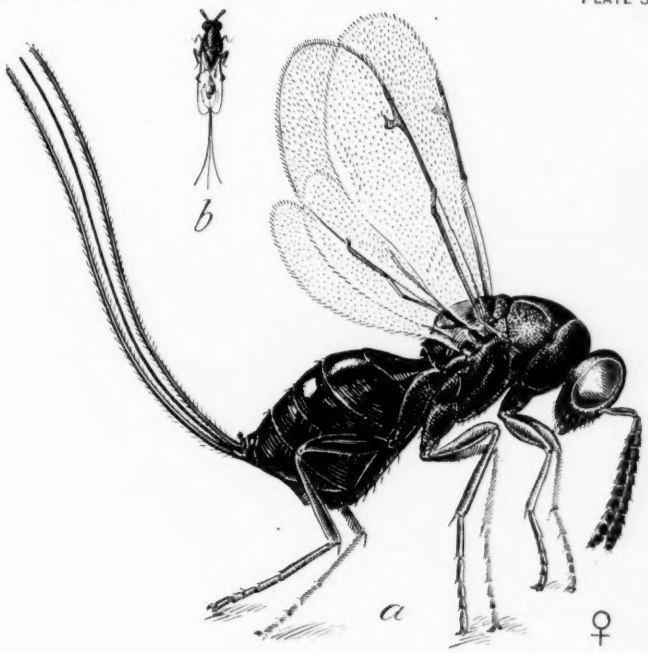
(8) HORVATH, Geza.
1911. A magyar entomologusok tömörülése. *In* Rov. Lapok, kötet 18, füzet 1, p. 1–3.

(9) CROSBY, C. R.
1912. Notes on Syntomaspis druparum Boh. and Ichneumon nigricornis Berger. *In* Canad. Ent., v. 44, no. 12, p. 365–366.

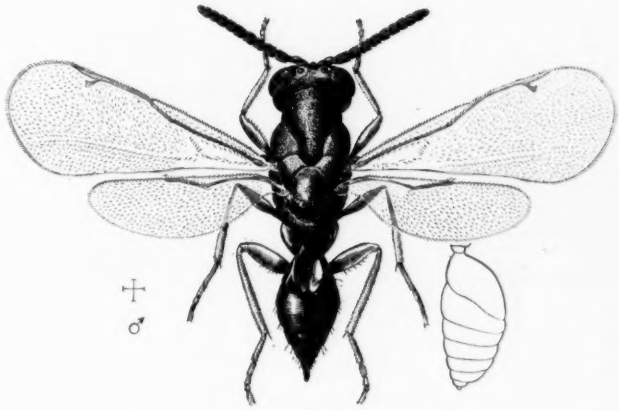
PLATE 37

Syntomaspis druparum:

A.—Adult female. *a*, greatly enlarged, *b*, × 3. (Original.)
B.—Adult male; outline of abdomen, lateral view, at right. Greatly enlarged. (Original.)



A



B

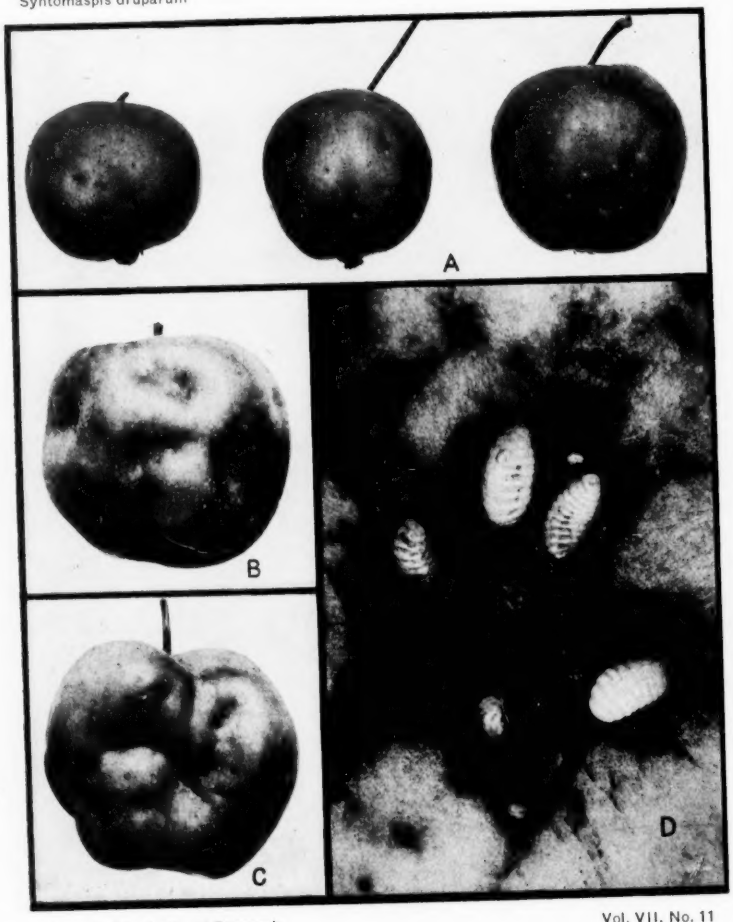

A
B
C
D

PLATE 38

Syntomaspis druparum: Apple injury and hibernating larvæ

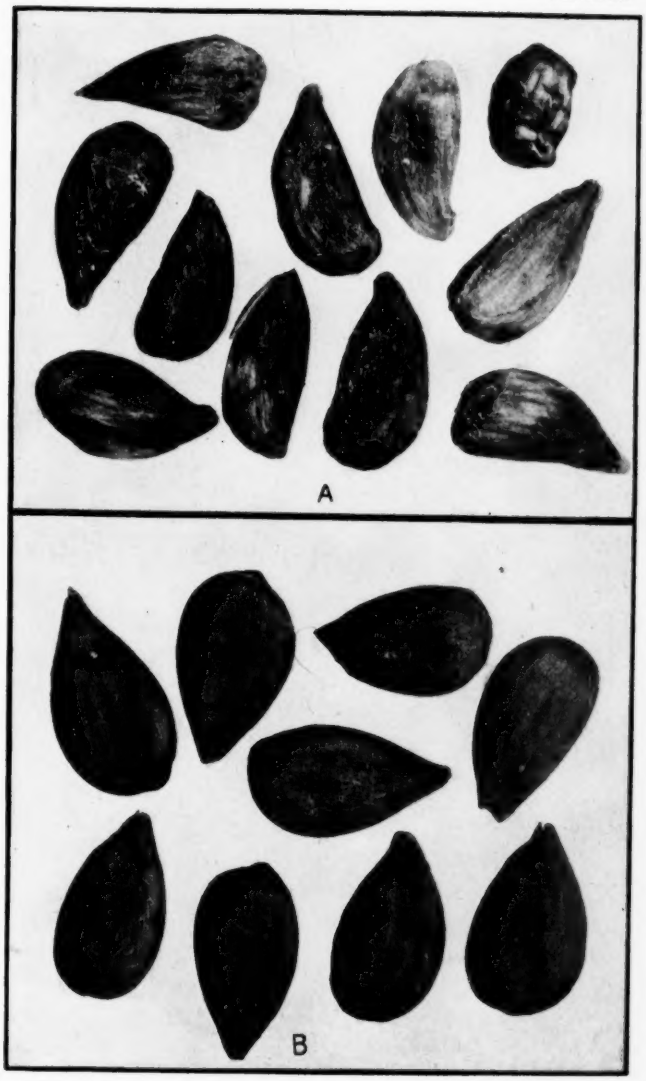
A.—Usual type of injury resulting from oviposition. Natural size.
B, C.—Extreme type of injury resulting from oviposition. Natural size.
D.—Hibernating larvæ within seeds of an apple. Greatly enlarged.

66847°—16——4

PLATE 39

Syntomaspis druparum: Infested and sound seeds of apples

A.—Infested seeds. Much enlarged.
B.—Sound seeds. Much enlarged.


A
B

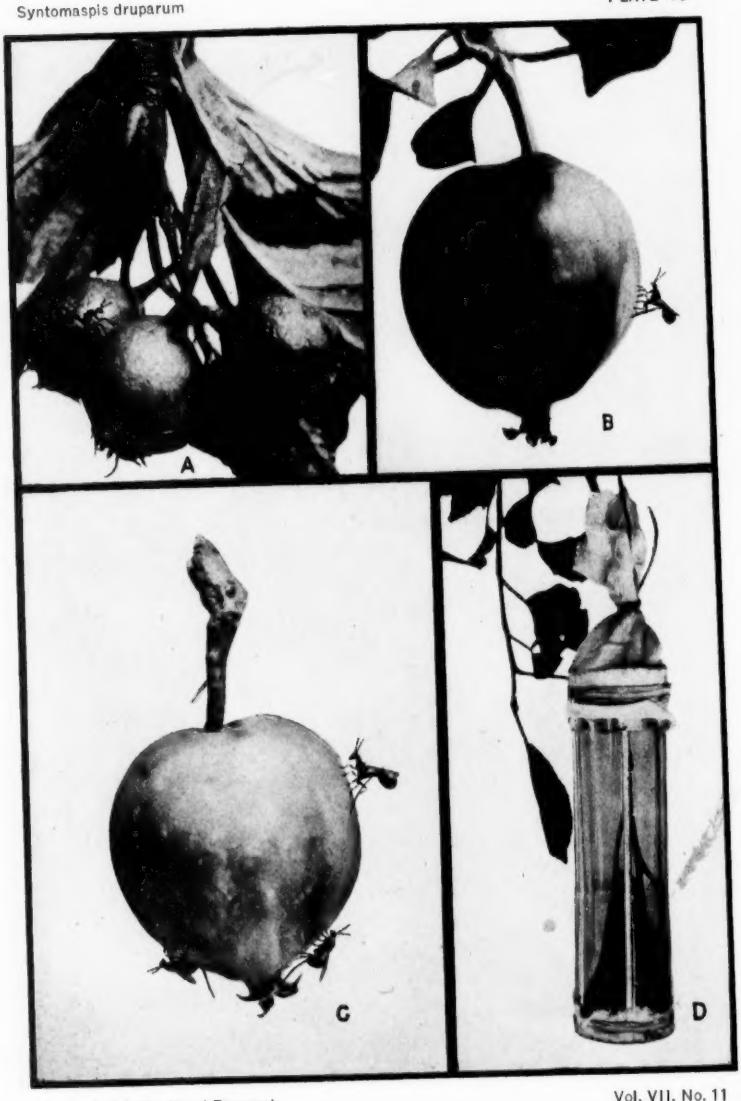

A
B
C
D

PLATE 40

Syntomaspis druparum: Oviposition

A.—Female ovipositing in fruit of *Crataegus* sp. Photographed from life. × 2.
B, C.—Oviposition in apples. Photographed from life. × 2.
D.—Mica cage used in the life-history studies of *Syntomaspis druparum*. × ⅓.